PROBLEMS IN BOTANY

EIKENBERRY

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BY

W. L. EIKENBERRY
ASSOCIATE PROFESSOR OF EDUCATION, UNIVERSITY OF KANSAS

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PREFACE

The rapid development of our country during the last few years has brought about a more general recognition of the great importance of the basic industry of plant production and of the necessity of applying the scientific method to this industry. This recognition emphasizes the importance of the study of the laws of plant growth, whether under the name of botany or of agriculture.

In presenting this manual it is the intention to place before high-school pupils a series of problems which have to do with the activities of plants and with their relations to human interests.

The problem method of presentation has been used. The experience of the best teachers shows that the interest of pupils is better maintained when, so far as practicable, each laboratory exercise is presented as a definite problem, the solution of which must be achieved by the pupil with only such assistance as will enable him to apprehend the problem and secure the necessary data. Furthermore, the experiences to which it is expected that the pupils will apply their scientific training present themselves as discrete problems, and it is therefore highly desirable, educationally, that their school work should tend to produce in them the habit of solving environmental problems in a scientific manner. At the same time it is recognized that there are some topics in botany as in any other science that do not lend themselves readily to statement in the form of problems. The author has not hesitated to depart from the problem method of attack in the case of individual exercises when another form appeared desirable.

The manual is organized about the activities of plants rather than about their structures. The leading exercises are concerned

with problems regarding the activities of plants as living things. Questions regarding structure naturally arise in consequence of the study of function, and structures are studied at the time when, and in so far as, they contribute to an understanding of the life activities of plants. The primary sequence of topics is physiological rather than anatomical.

A textbook should be used throughout the course, and references to the two books by Bergen and Caldwell are provided. Discussions, and to a considerable extent the names of structures, should be secured from the textbook, which should be used as a reference book in connection with the laboratory manual.

The author has sought to make the directions to pupils as detailed as possible without destroying opportunity for initiative on the part of the pupil or solving his problems for him. The study or experimentation called for in each case should put a pupil in possession of the facts upon which he may base his conclusion. The pupil should be allowed to think the matter through to a conclusion, even if his conclusions are sometimes in error.

Printed directions do not make a teacher unnecessary. The teacher should require dependence upon the outlines for all information furnished therein, refusing to answer questions when the guidance sought is contained in the printed directions, in order that his time may be reserved for the more important phases of teaching. There rests with the teacher the responsibility for calling attention to errors of technique, guiding the thinking of those who need assistance, presiding over the general discussions in which the class compares results and detects errors of fact or reasoning, and finally checking up the whole matter by examination of notes and drawings.

A record of all laboratory work should be kept by each pupil. Memoranda should be made during the progress of an experiment, and these should serve as the basis of detailed notes which should be written immediately at the close of the exercise. The general character of the notes is discussed in connection with the directions for work in the first few exercises. However, no printed suggestions to pupils will secure good notes; the responsibility rests with the teacher. Few pupils will write good notes

if carelessly written ones are accepted by the teacher, but most pupils will write notes which come up to the standard maintained by the teacher.

Notes and drawings should be collected, examined, and graded weekly, and they should be returned to the pupils promptly. By this means errors are detected at once, and any tendency to postpone note-writing may be corrected.

The amount of drawing which is called for in this manual is not great, and most of the necessary drawings should be diagrammatic. The results of investigation of the psychology of drawing in biological study have shown [1] that there is little pedagogical value in the detailed drawings the making of which formerly occupied such a large place in biological courses, but that diagrammatic drawing is a very valuable teaching device. Diagrams are properly employed to represent the pupil's ideas regarding the relations of things; detailed drawing, to make clear such descriptive facts as cannot be readily represented in words.

It has been found advantageous to take the class out of the laboratory and into the field, forest, or garden for many exercises which are sometimes worked out within the laboratory, and certain other exercises ought, if possible, to constitute home projects, as indicated in connection with the exercises. It is always preferable to take the class to the materials in their natural surroundings rather than to bring the materials into the laboratory, if the former course is practicable. Each outdoor excursion made by the class should be directed to the solution of a definite problem and should be characterized by the same kind of serious work as characterizes ordinary laboratory sessions. Such short excursions, restricted to a single problem, are better assimilated than are longer and more or less confused excursions. They offer the further advantage of avoiding the administrative difficulties which have sometimes put field work in disfavor.

No directions are given for all-day field trips. Such extended excursions should be planned whenever possible, but local conditions vary so widely that it is obviously impossible to write directions that will be generally applicable. The botanical results

[1] F. C. Ayer, Psychology of Drawing. Warwick and York.

of such a trip will depend principally upon the skill and the enthusiasm of the teacher.

It is not probable that any school will care to use all of the exercises presented herewith. In some cases definite alternatives have been suggested. In other cases traditional exercises have been retained because under some circumstances they are valuable. Thus the exercises involving rather careful microscopic study of the morphology of the higher plants will undoubtedly be omitted by most schools, but some schools may find them useful.

Examination of the apparatus list published herewith will indicate that expensive equipment is not essential, and it will be found that most of the items will be available for use in other science courses as well. The principal item of expense, microscopes, may be eliminated if necessary, but every school ought to possess at least one instrument. In many cases a good microprojection outfit will be found more satisfactory than a full equipment of microscopes. While extreme economy is justified on the part of schools with very limited resources, there is no point at which the proper expenditure of funds makes for efficiency and economy to a greater extent than in the provision of proper laboratory equipment. Such equipment releases the teacher from an enormous amount of detail work and enables him to concentrate his attention upon the needs of the children instead of compelling him to give the major part of his time to the mere mechanics of instruction.

The author wishes to express his deep indebtedness both to the literature of botany and of botanical education and to his instructors, colleagues, and pupils who together have made this work possible. Particularly does he gratefully acknowledge the instruction, advice, and inspiration received from Dr. Otis W. Caldwell, to whose encouragement is largely due both the inception and the completion of this volume.

W. L. E.

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INTRODUCTION

The informal or formal study of plant life has been a constant factor in the development of the human race, because men have always depended upon plants as direct or indirect sources of food, clothing, and shelter. Indeed, one of the most conspicuous features of the evolution of civilization has been the increasing control of plant life so that it may more readily and more abundantly meet the economic and æsthetic needs of men. In recent times plant study has been organized in such ways that it not only meets men's immediate needs but, by means of intellectual consideration of its principles, has proved to be of the highest educational value.

When the subject of botany was definitely organized upon the basis of the evolution of the plant kingdom, with closely graded type studies to illustrate increasing complexity, this coherent and progressive method of study marked an important change from an unorganized study either of the medicinal uses of plants or of their classification. This type-study method was adopted almost or quite to the exclusion of any study of the economic, æsthetic, and intellectual control of plants. It soon became clear that a serious loss had been sustained and that courses were needed which would enable beginners to use coherent and progressive thinking with those topics of study which relate to control and use of plants quite as fully as with the study of how plants have come to be what they are. It has been found best to have these topics of study organized about botanical questions or problems which most frequently occur in human experience, in order that the study may make the largest contribution to purposeful thought and action.

The purposes stated above have guided the preparation of the texts in botany with which this laboratory manual is designed

to be used, and also of the manual itself, which provides for the essential first-hand experience with plants. Such experience is of the highest importance. The manual represents a distinct advance in botanical instruction in secondary schools because of the way in which it insures abundant experience with plants. It provides outlines by means of which the laboratory presentation of botanical study, as well as the text presentation, may be in accord with the most recently defined ideals for science work in secondary education.

Textbooks and laboratory manuals of botany are of two types, — office made or made through experience. This manual, like the texts with which it is designed to serve, is the result of many years of successful experimentation in secondary-school teaching. This method of developing an outline of study seems to be the only one really worthy of science. If trial, correction, retrial, selection, and elimination — that is, the experimental basis — are essential in the development of our knowledge of science, surely the same experimental basis is essential to the development of courses of science study.

Since this manual is the result of such careful experience, it should prove of great value to young people who have the opportunity of using it.

OTIS W. CALDWELL

PROBLEMS IN BOTANY

EXERCISE 1

PLANTS AND WATER

Materials. Several potted plants of coleus or anything else that is rather delicate. The plants used should be as nearly alike in size and general appearance as possible.

Directions for work. Place all of the plants in a warm, dry, light place. Water one half of them freely, but do not water the remainder during the experiment.

Examine the plants daily. After several days, or possibly within one day, differences in the appearance and behavior of the two lots of plants may be seen.

State on paper what differences between the plants you see. What explanation can you offer for the change which has occurred in one lot of plants? What reasons have you for this explanation? Is there any way in which you can test the accuracy of your explanation?

Make a list of all the questions which come into your mind as a result of this experiment, and preserve this list for further use as you continue the study of the relation of water to plants.

Notes. It is usually desirable to make a written record of any laboratory study. Such a record may be brief; it must be accurate. It should be written in good English and with as much care as a theme in the English class. If the exercise is an experiment, as this one is, there will be three parts to the composition, as suggested below, and each of the parts will commonly appear as a separate paragraph. Write notes on this exercise according to the following suggestions:

1. Give an account of what was done, either by the instructor or by you, in carrying out the experiment. Be careful to omit nothing that might in any way influence the result of the experiment. Make it clear enough so that an absent classmate would be able to perform the experiment at a later time with no other guide than your notes. Illustrate by sketches if it will assist you.

2. What results did you observe? State the facts observed, without your opinions. Make the statement as definite as possible. When the results can be expressed in figures (as in Exercise 3) these figures should be given.

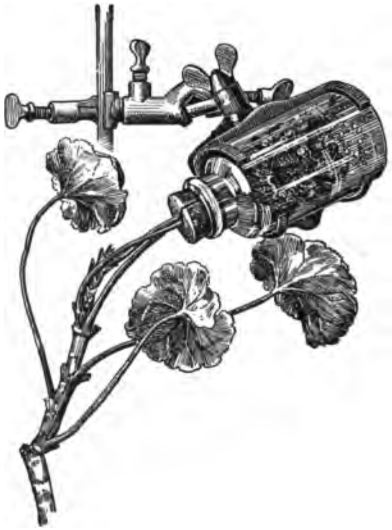
3. State your conclusions. What have you learned from the experiment? What is your explanation of the meaning of the observed results? What are the reasons which convince you that your explanation is correct? What further question or what additional experiment does it suggest?

EXERCISE 2

DOES WATER EVAPORATE FROM SHOOTS?

Materials. Geranium plant; two six-ounce, wide-mouthed bottles; cork stopper or wad of cotton; support with clamp.

Directions for work. While the geranium is suggested for this study, almost any common plant will answer if the leaves are small enough to be treated as directed below. Trees or shrubs out of doors may be used.



Insert the end of a leafy shoot into one of the bottles and support the bottle in such manner that the shoot will be in approximately natural position. Select a cork stopper which fits the bottle and punch a hole through it large enough to accommodate the stem which has been inserted into the bottle. Split the stopper through the center of the hole and place the two halves in the neck of the bottle with the stem in the hole. (See Caldwell and Eikenberry, "Elements of General Science," Fig. 62.) If a large stopper is not at hand, the neck of the bottle may be plugged with cotton. For purposes of comparison, support a similar bottle, stoppered but with no leaves in it, near the first. If a potted plant is used, place it in a light place.

Examine at intervals during the next hour in order to determine whether there is evidence that water is given off.

What are the facts that you observe? What are your conclusions regarding the loss of water from shoots?

Review the directions for writing notes as given in connection with the previous exercise, and write notes on this exercise.

Reference

BERGEN and CALDWELL. Practical Botany, p. 18.

EXERCISE 3

HOW MUCH WATER MAY EVAPORATE FROM A PLANT?

Materials. A potted plant; sheet of dentist's rubber large enough to inclose the pot; balance and weights.

Directions for work. In order to determine the answer to the question above, proceed as follows:

Water the pot thoroughly. Wrap it in the sheet rubber and tie the rubber about the stem so that water is prevented from evaporating from the soil or pot.

Weigh the plant at hourly intervals during the daytime for at least two days. The pupils may take turns in weighing throughout the day, the weights being recorded on the blackboard for the benefit of all.

Tabulate the results as follows:

DATE	HOUR	WEIGHT	HOURLY LOSS	TOTAL WATER EVAPORATED

Reference

BERGEN and CALDWELL. Practical Botany, p. 18.

EXERCISE 4

WHAT HINDERS THE RAPID EVAPORATION OF WATER AND COMPLETE DRYING OF THE LEAF?

Materials. Leaves of lily, amaryllis, hyacinth, iris, or similar plant; sharp knife.

Directions for work. With the knife make a slight cut obliquely through the surface layer of the leaf. Catch hold of the surface layer at the edge of the cut with the thumb and the knife blade, and peel off some of it. This is usually more easily accomplished on the lower side of the leaf. The thin layer removed is the epidermis.

Remove the epidermis from as much as a half-inch or quarter-inch square of leaf and allow a piece of leaf with epidermis removed to lie on the desk alongside a piece with epidermis uninjured for as long as an hour if possible. Note the changes that take place in either piece.

While waiting for the progress of the above experiment, examine the epidermis carefully. Note especially its thickness, color, and degree of transparency. Examine also the material which occupies the interior of the leaf, noting its color, thickness, and texture. Where does most of the moisture in the leaf appear to be found?

Compare the two pieces of leaf which have been exposed on the desk as directed above. What changes have taken place? What are you able to conclude regarding the value of the epidermis to the leaf?

Write notes as in the preceding exercises.

References

BERGEN and CALDWELL. Practical Botany, pp. 13, 14.

BERGEN and CALDWELL. Introduction to Botany, pp. 34, 35.

EXERCISE 5

STRUCTURE OF EPIDERMIS

Materials. Compound microscope; glass object slides and cover slips; leaf epidermis.

Directions for work. Mount a small piece of epidermis in water on a slide and cover with a cover slip. (Secure detailed directions for using microscope from the teacher.) Examine with low and high power.

Note that the epidermis is made up mostly of rectangular units, called cells, as a pavement is composed of bricks. Certain of the cells are bean shaped and are found in pairs.

Do you find spaces between cells forming openings through the epidermis? If so, describe and locate them clearly enough to enable any one else to find them readily by the aid of your notes. Such openings are called *stomata* (singular *stoma*).

How do these openings assist in explaining the loss of water by evaporation?

References

BERGEN and CALDWELL. Practical Botany, pp. 13, 14.
BERGEN and CALDWELL. Introduction to Botany, pp. 34–36.

EXERCISE 6

BY WHAT ROUTE DOES WATER REACH THE LEAVES?

Materials. Leafy branches of tree or shrub, preferably at least one-half inch thick at base; soft leafy stems, such as geranium, coleus, celery, or almost any common weed or herbaceous flowering plant, but semitransparent stems, as yellow coleus, are best; eosin or red ink.

Directions for work. Color some water with eosin or with red ink. Stand freshly cut stems with lower ends in the colored water. Place the experiment in a sunny place for later examination.

1. *Woody stems.* When the branches have been standing in the colored water for some hours, remove them from the solution and cut sections at various heights along the stems. Also split the pieces lengthwise. Trace the path of the water into the branches and, if possible, to the leaves.

Does the water travel in the pith, the wood, or the bark? (See textbook for definition of terms.) What can you learn about the distribution of water throughout the leaves?

2. *Herbaceous stems.* From twenty minutes to an hour is sufficient to secure results with such stems as geranium or coleus.

Section and examine in the same way as directed for woody stems. Note carefully the path of the water.

References

BERGEN and CALDWELL. Practical Botany, p. 11.
BERGEN and CALDWELL. Introduction to Botany, pp. 12, 13.

EXERCISE 7

STRUCTURE OF STEMS, WITH SPECIAL REFERENCE TO WATER CONDUCTION

Materials. Cross sections of oak branch or trunk three to six inches in diameter; microscope slides with sections of woody stems and herbaceous stems.

The oak sections may be prepared by cutting a seasoned oak branch into sections about one inch long and carefully smoothing one cut surface with fine sandpaper. If red oak is used, the distinction between sapwood and heartwood will be prominent. The sections may be retained as permanent laboratory apparatus if the surfaces are oiled and varnished.

Directions for work. 1. Examine the smoothed surface for water-conducting tubes appearing in cross section as round pores, just visible to the naked eye but easily seen with a lens. These pores may be filled with dust due to the sandpapering. The dust may be removed by a vacuum cleaner, or a part of the surface may be smoothed with a sharp knife.

How does the location of the pores correspond with the location of the water-conducting region discovered in the preceding exercise? Are the pores scattered at random through the branch, or are they arranged in any definite way? If a new layer of wood grows each year, what relation do the pores appear to have to this annual growth?

Count the annual layers to determine the age of the tree. About how many years did it take this tree to increase one inch in diameter?

Make a diagram of the cross section showing location of pith, wood, bark, annual layers, medullary rays, heartwood, and sapwood. (See textbook for definitions and for assistance in identifying structures.)

2. With the compound microscope examine thin sections of woody twigs two or three years old. Identify wood, pith, bark, annual layers, medullary rays. Represent the cross section diagrammatically and label the structures named above. Draw a few cells from the wood, including at least one large pore.

EXERCISE 7 (*Continued*)

Study a cross section of a coleus or other herbaceous stem and find the water-conducting tissue, comparing thin sections with stems colored as in Exercise 6. When you have accurately located the water-conducting tissue, study its structure and draw a few cells. Do they resemble any of the cells found in the woody stems? Is the water conducted in the wood or in the pith?

By the aid of your textbook find the pith, fibrovascular bundles, cortex, epidermis. Make a diagram of the cross section and label the parts.

The wood and bark of older stems result mainly from the growth of the fibrovascular bundles, but the details cannot be followed out in elementary laboratory work. However, the wood part of the bundle (inner part) and the bark part (outer part) may be distinguished along with the line of growing cells, cambium, which lies between wood and bark.

References

BERGEN and CALDWELL. Practical Botany, pp. 11–13, 44–53.

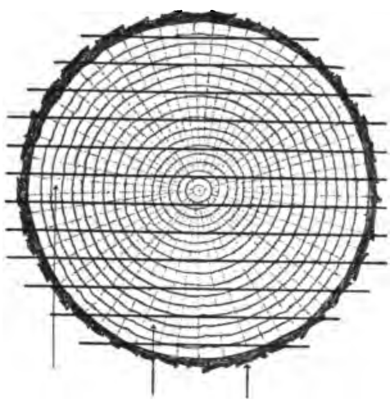
BERGEN and CALDWELL. Introduction to Botany, pp. 11, 12, 62–68.

EXERCISE 8

ORNAMENTAL CHARACTERISTICS OF OAK WOOD

Materials. Cross sections of an oak log about three inches in diameter, as used in Exercise 7; a section of a seasoned white oak log about four or five inches in diameter and six inches long or longer.

Directions for work. With the cross sections of wood in your hands identify pith, heartwood, sapwood, annual layers, medullary rays, inner bark, and outer bark. Note whether the specimen represents a slow-growing or a rapid-growing species. Is it ring-porous or diffuse-porous?



Cut a section five or six inches long from the larger log and saw lengthwise into boards about one-half inch in thickness. Smooth both sides of these boards with a plane and sandpaper. The sawing and rough planing should be done on the power saw and planer in the school shops if the school possesses such machinery.

One or two of these boards will show surfaces that are nearly parallel with the medullary rays. These correspond with "quarter-sawed oak." Find these boards and mark them. In the remainder of the boards the surfaces are tangential to the annual layers. They may be called "plain-sawed" boards.

Identify sapwood, heartwood, medullary rays, and wood pores on the planed surfaces of each board. Describe each of these clearly enough for purposes of identification by a beginner.

Determine the relation of the structural elements of the wood mentioned above to the appearance of the wood in finished furniture in the following manner. Treat one plain-sawed surface with linseed oil, a second with a dark wood-filler, and a

third with a brown stain, following manufacturers' directions in each case. After they have dried, study the boards to determine how the summer wood, spring wood, sapwood, and medullary rays react to the finishes. Does sapwood or heartwood finish better? To which of the structural elements of the wood is the "figure" of the wood principally due?

Repeat the above with the quartered surfaces and determine the same facts.

Compare with oak furniture, floors, doors, etc. and classify these as to excellence of materials and finish.

References

BERGEN and CALDWELL. Practical Botany, pp. 44–52, 391–393.
BERGEN and CALDWELL. Introduction to Botany, pp. 109, 110.

EXERCISE 9

PHYSICAL CHARACTERISTICS OF OAK WOOD

Materials. Sticks of seasoned white oak one inch square and two feet long; other sticks of the same wood but only one-half inch square; several rectangular blocks of oak; several small boards of green oak, which may be sawed from a freshly cut log as directed in Exercise 8. Some boards must be radial and others tangential.

Directions for work. What is the weight of oak wood? Determine this by measuring several of the rectangular blocks, weighing them, and calculating the weight per cubic foot. Average results from the several blocks.

What is the strength of oak wood? Support a stick of oak at two points, as by laying it across two bricks. Measure the distance between the places of support. Note the approximate amount of bending under different strains, as when persons of known weight stand on a stick at a point midway between the supports. If the stick is broken, note the weight which breaks it.

What is the difference, if any, between plain and quartered oak as to amount of warping? Select several of the green boards for a drying test, making sure that in the lot there is at least one radial (quartered) board and one tangential (plain) board. Expose them to the air and heat, but see that all boards have as nearly as possible the same exposure. Support in such manner that the air has access to both sides of each board, and turn them daily in order that both sides may be equally exposed to drying.

Which boards warp the most? Which the least? Which side of a plain-sawed board becomes concave?

In your notes sum up what you have learned about the weight, strength, and seasoning of oak wood.

References

BERGEN and CALDWELL. Practical Botany, pp. 393–395.

BERGEN and CALDWELL. Introduction to Botany, pp. 62–67, 107, 108.

"Mechanical Properties of Woods grown in the United States," *Circular No. 213*, Forest Service, U. S. Dept. Agr.

CLINE and HEIM. "Tests of Structural Timbers," *Bulletin No. 108*, Forest Service, U. S. Dept. Agr.

EXERCISE 10

GENERAL CHARACTERISTICS OF HARD WOODS

Materials. Blocks, boards, or small logs of a large variety of hard woods; wood sections.

Directions for work. Study the specimens of woods available, noting the characteristics with sufficient fullness to enable anyone to discriminate between them by the use of your notes only. Note especially color, apparent weight, medullary rays, thickness of annual layers, ring- or diffuse-porous, size of pores, appearance of finished surfaces, and any individual peculiarities.

References

BERGEN and CALDWELL. Practical Botany, chap. xxii.

BERGEN and CALDWELL. Introduction to Botany, pp. 62–68, chap. viii.

SUDWORTH and MELL. "Circassian Walnut," *Circular No. 212*, Forest Service, U. S. Dept. Agr.

MAXWELL. "Uses of Commercial Woods of the United States: Beech, Birches, and Maples," *Bulletin No. 12*, U. S. Dept. Agr.

EXERCISE 11

CHARACTERISTICS OF SOFT WOODS

Materials. Boards, blocks, and sections of gymnosperm woods, such as pine, cedar, hemlock, redwood, fir, spruce, and cypress.

Directions for work. Study as directed in Exercise 10. In addition, note character of wood in relation to presence of pores. If possible, examine thin cross sections with a microscope. Discuss the differences between the wood of angiosperms and that of gymnosperms (so-called hard woods and soft woods).

References

BERGEN and CALDWELL. Practical Botany, chap. xxii.

BERGEN and CALDWELL. Introduction to Botany, chap. viii.

HALL and MAXWELL. "Uses of Commercial Woods of the United States: I. Cedars, Cypresses, and Sequoias," *Bulletin No. 95*, Forest Service, U. S. Dept. Agr.

HALL and MAXWELL. "Uses of Commercial Woods of the United States: II. Pines," *Bulletin No. 99*, Forest Service, U. S. Dept. Agr.

CLINE and KNAPP. "Properties and Uses of Douglas Fir," *Bulletin No. 88*, Forest Service, U. S. Dept. Agr.

EXERCISE 12

STRUCTURE OF A MONOCOTYLEDONOUS STEM

Materials. Stems of corn; pieces of palm stem.

Directions for work. Not all stems are like those studied. The stems studied in the preceding exercise belong to the dicotyledonous group; the corn and palm are representative of the monocotyledons. (See illustrations and discussions in "Practical Botany," pp. 335–350.)

Examine the cross section of a corn stem, noting the distribution of the fibrovascular bundles. Also cut the stem lengthwise and trace some of the bundles.

By the use of colored water follow the path of the water through the stem, as in Exercise 6.

Compare the corn stem with the palm. Make a diagram showing how the bundles are arranged.

References

BERGEN and CALDWELL. Practical Botany, pp. 53, 54, 335–350.
BERGEN and CALDWELL. Introduction to Botany, p. 68.

EXERCISE 13

WATER-CONDUCTING TISSUES OF A ROOT

Materials. Piece of root from a tree. Root should be about an inch in diameter.

Directions for work. Cut cross sections of the root. Compare its structure with that of the stem, which it closely resembles. Note the large water-conducting pores.

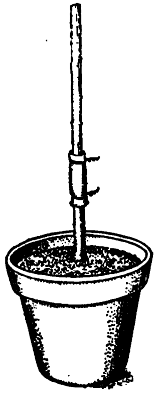
References

BERGEN and CALDWELL. Practical Botany, pp. 6–10, 24, 25.
BERGEN and CALDWELL. Introduction to Botany, pp. 9, 10, 20–25.

EXERCISE 14

HAS A ROOT THE ABILITY TO ABSORB WATER AND TO ASSIST IN RAISING IT UP THE STEM?

Materials. Vigorous plant with a single firm stem about one-fourth inch in diameter; glass tube about one-fourth inch in diameter and ten to twelve inches in length, preferably with bore of small diameter; rubber tubing; copper wire about No. 18; pliers.



Either a potted plant or one growing in the soil out of doors may be used, but it will be difficult, if not impossible, to secure results with plants that are near the end of their season's growth. A potted bryophyllum plant has been found very satisfactory.

This exercise and the two following may be set up at the same time by different members of the class.

Directions for work. Cut the stem as close to the root as possible. To the stub remaining in connection with the root attach the glass tube, using a short piece of rubber tubing as connection and bringing the glass tube and stem into contact within the rubber tube. Make sure of a tight joint by wrapping a piece of copper wire around the rubber tubing at each end and tightening by twisting the ends together with the pliers.

Water the plant thoroughly and make observations at hourly intervals, recording the height of the liquid in the tube.

What are your conclusions?

References

BERGEN and CALDWELL. Practical Botany, pp. 9, 10.
BERGEN and CALDWELL. Introduction to Botany, pp. 22–24.

EXERCISE 15

ABSORPTION BY A ROOT

Materials. Large carrot, beet, or other large root; one-hole rubber stopper; glass tube; carpenter's auger.

Directions for work. With the auger bore a hole into the upper end of the root, nearly fill the hole with sugar, and insert the stopper. Place the glass tube in the hole in the stopper. Tie the stopper in with copper wire.

Set the root in water and observe hourly for several days, noting the height of the liquid in the tube.

What are your conclusions regarding absorption by roots?

References

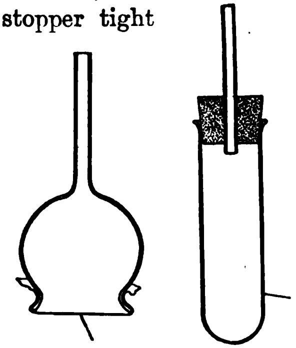
BERGEN and CALDWELL. Practical Botany, pp. 6–11, 79, 80.
BERGEN and CALDWELL. Introduction to Botany, pp. 9, 10, 41, 42.

EXERCISE 16

OSMOSIS

Materials. Several forms of apparatus may be used, choice being largely a matter of convenience. The following are suggested:

1. A "diffusion shell," as sold by supply companies, may be filled with molasses or with sugar solution, stoppered with a one-hole rubber stopper with glass tube inserted, and placed in a vessel of water. Make the stopper tight by wrapping with wire or waxed cord.



2. A piece of soaked parchment paper may be tied over the large end of a thistle tube which has been previously filled with molasses or sugar solution. The bulb of the thistle tube should then be immersed in water. There is often difficulty in preventing leakage due to the folds in the paper.

3. The Lyon osmometer shown in the cut may be assembled, as illustrated. It is cheap, easily assembled, and certain in its action. See apparatus list for maker.

Directions for work. Assemble the apparatus chosen and make hourly readings.

Note that the essential features are a membrane permeable to water (parchment paper), separating a dense solution (molasses) from a much less dense solution (hydrant or well water). What resemblances to a root can you see? Does water tend to move toward the denser or toward the less dense solution in such cases as the above? Do you know whether plant sap contains substances in solution? If so, what substances are known to be sometimes present?

References

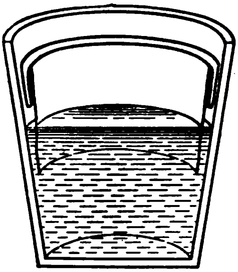
BERGEN and CALDWELL. Practical Botany, pp. 79, 80.
BERGEN and CALDWELL. Introduction to Botany, pp. 41, 42.

EXERCISE 17

DOES THE FORM AND STRUCTURE OF THE ROOT FAVOR ABSORPTION?

Materials. **Low covered glass dish, as a petri dish, and clean filter paper or blotting paper, or drinking glass and filter paper; small seeds, such as mustard, radish, clover, or wheat.**

Directions for work. Place a layer of blotting paper or several layers of filter paper on the bottom of a dish and saturate it with water. Sow seeds thinly on the wet paper and cover. Set in a warm place several days, until the roots of the germinating seeds have reached the length of a half inch.



If preferred, seeds may be sown in the fold of a piece of filter paper, as illustrated in the figure. It is necessary to provide holes through the paper to allow the roots to grow down into the water. These may be made with a needle.

Examine the roots without exposing them to the air of the room. Find and identify the root hairs. Note their abundance, size, and distribution on the roots. Mount one of the root tips on a slide and examine the root hairs with the compound microscope, if possible.

In what way might the root hairs aid in the absorption of water?

References

BERGEN and CALDWELL. Practical Botany, pp. 6–9.
BERGEN and CALDWELL. Introduction to Botany, pp. 9, 10.

EXERCISE 18

RELATION OF ROOT HAIRS TO SOIL

Materials. Seedling plants growing in sand, loose soil, or sawdust.

Directions for work. To determine whether the root hairs have any close relation to the soil, gently remove a plant which is growing in very loose soil or in sand or sawdust. After noting how much soil adheres, gently shake the plant and note results. Then wash the roots by moving them to and fro in a vessel of water. Finally, mount one of the washed roots for examination with the hand lens or microscope.

Do you find that washing removes all the soil? What is your opinion regarding the original position of the root hairs with relation to the soil particles? Do the root hairs appear to be so placed as to favor absorption of the water which moistens the surfaces of the soil particles?

References

BERGEN and CALDWELL. Practical Botany, pp. 6–9.
BERGEN and CALDWELL. Introduction to Botany, pp. 9, 10.

EXERCISE 19

COMPOSITION OF SOME PLANT SUBSTANCES

Materials. Dry starch; bits of wood; test tubes; bunsen burner or alcohol lamp.

Directions for work. In the previous study it has been found that plants take up from the soil both water and substances dissolved in the water. Is the material of which the plant is composed secured in this way? Does starch, for instance, enter the plant from the soil in solution in water? Is the wood composed of materials which may have entered in this way? We may start an investigation of these matters by decomposing plant materials to determine of what they are composed. Proceed as follows:

Place a small amount of dry starch in a test tube. Heat it slowly over a flame. Does anything collect on the sides of the tube in the upper and cooler part? So far as you can tell, what is this substance? Continue heating until the residue in the bottom of the tube no longer changes in appearance. Note the black color of this residue. It is carbon. Remove part of it, if possible, and find out whether it will burn.

When the tube has cooled, add water and find out whether the carbon is soluble in water. Do you believe that the carbon could have entered the plant in solution in water, through the roots? Is there, so far as you can learn, any large amount of carbon in the soil? Is carbon commonly added to soils as a fertilizer?

Repeat the experiment with chips of wood in another test tube. Compare the results in this case with those noted above.

On the basis of what you have learned in this experiment, does it appear probable that all of the materials which enter into the composition of a plant have been secured from the soil?

EXERCISE 20

PRODUCTION OF STARCH IN LEAVES

Materials. Fresh leaves, both green and variegated green and white (such as geranium), which have been exposed to the sun for several hours; alcohol; iodine solution; glass or metal beaker or cup; water bath.

Directions for work. 1. Dip each of the leaves in boiling water for a few seconds in order to kill the leaf tissues. Transfer them to alcohol in a beaker and keep the alcohol warm over a water bath for about ten minutes. When the leaves are removed they should be without green color. Where has the green coloring material (chlorophyll) gone?

2. Place a number of the leaves in a weak solution of iodine (tincture of iodine) and allow them to remain in the solution about ten minutes or until decided changes of color are seen. Note the location of the colored parts, particularly in the variegated leaves.

3. Put a small quantity of starch in a test tube, add a few drops of iodine solution, and shake the tube. Note the resulting color. Boil the water for a few minutes, cool, and add iodine. Note color.

4. What substance did the test reveal in the leaves? Did its location in the variegated leaves have any relation to the location of the chlorophyll, and if so, what?

References

BERGEN and CALDWELL. Practical Botany, pp. 15–17.
BERGEN and CALDWELL. Introduction to Botany, pp. 37–40.

EXERCISE 21

THE CHLOROPLASTS

Materials. Thin leaves of a water plant, such as *Elodea* or *Potamogeton*, or leaves of a moss (these should have been exposed to direct sunlight for some hours before the study is made); compound microscopes.

Directions for work. Mount a piece of a leaf, or pieces of several leaves, on a slide for examination with the microscope. Observe the cells of the leaf with low power and high power.

Where does the chlorophyll occur in the cells? Describe the cells and the chlorophyll bearers (chloroplasts).

To determine the location of starch in the leaf cells, remove the water from the slide by touching a piece of blotting paper or filter paper to the edge of the cover slip. Add dilute iodine at the other edge of the cover. Examine the leaves for evidences of starch and note its relation to the chloroplasts.

NOTE. From the textbook it may be learned that starch is present in the leaves, as shown by the experiment, because it is manufactured there. Sugar is present for the same reason, and more commonly than starch, but there is no equally convenient test for its presence. The following exercises will take up some of the conditions necessary for the making of such foods.

References

BERGEN and CALDWELL. Practical Botany, pp. 14, 15.
BERGEN and CALDWELL. Introduction to Botany, p. 37.

EXERCISE 22

IS LIGHT NECESSARY FOR STARCH-MAKING IN LEAVES?

Materials. Two potted plants, or two small plants (as clover) growing-out of doors; water bath; beaker; alcohol; iodine.

Directions for work. Put one plant in a dark closet at least twenty-four hours before the experiment is to be performed, at the same time placing the other in a window where it is exposed to the rays of the sun for at least several hours preceding the experiment; or if potted plants are not available, select two clover. plants in a meadow and cover one of them with a bucket.

Gather several leaves from each plant, remove the chlorophyll, and test for starch as in Exercise 20.

What differences, if any, do you find between the leaves which have been in the dark and those which have been exposed to the light? What does this indicate about the necessity of light for starch-making in leaves (photosynthesis)?

References

BERGEN and CALDWELL. Practical Botany, pp. 15–17.
BERGEN and CALDWELL. Introduction to Botany, pp. 38, 39.

EXERCISE 23

IS AIR NECESSARY FOR PHOTOSYNTHESIS?

Materials. Plants; vaseline; benzine or gasoline; water bath; beaker; alcohol; iodine.

Directions for work. Air may be excluded from a leaf by covering the stomata with such a substance as vaseline. Select a plant which has been in the dark since the previous day. Rub vaseline over the surfaces of several leaves, being particularly careful to completely cover the lower surfaces. Place the plant in bright sunshine for several hours.

When the leaves have been exposed to the light long enough to have accumulated considerable starch, remove the vaselined leaves and several unvaselined leaves from the plant. Dissolve off the vaseline with benzine. Remove chlorophyll and test for starch.

Compare the vaselined leaves with the unvaselined leaves, noting the differences. What do these differences mean? What is your conclusion about the necessity of air for photosynthesis?

NOTE. Air is composed of several gases. This experiment does not attempt to show what part of the air is necessary for photosynthesis.

References

BERGEN and CALDWELL. Practical Botany, pp. 13–17.

BERGEN and CALDWELL. Introduction to Botany, pp. 34–39.

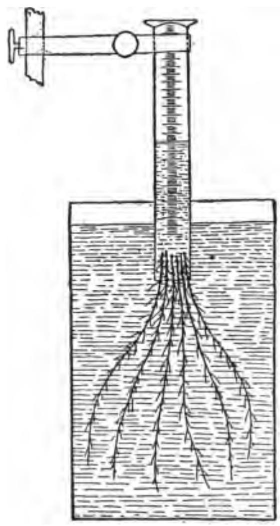
CALDWELL and EIKENBERRY. Elements of General Science, pp. 65, 66. Ginn and Company.

EXERCISE 24

A WASTE PRODUCT OF PHOTOSYNTHESIS

Materials. Submerged water plants, such as the common pond weeds.

Directions for work. 1. Place the plants in a large glass jar or aquarium filled with water. Allow the sun to shine upon it. After ten minutes observe the plants and look for evidence of any gas escaping from the plants. Darken the aquarium and note the effect. Try several degrees of shading and note effect, counting number of bubbles per minute, but always allowing several minutes for the new conditions to produce its effect.



The gas escaping may be collected by proper methods (see "Introduction to Botany," Fig. 27) and shown by tests to be oxygen, but experience shows that under laboratory conditions such tests are often unsatisfactory.

2. If a good projection lantern is available, the experiment may be performed as follows:

Place a branch of a water plant in water in a thin glass tank, which can be substituted for the slide carrier. Illuminate the plant by the electric lamp, which will project its image upon the screen. After some minutes the plant will begin to give off bubbles of gas.

This method offers the advantage of being available on cloudy days, and the experiment may be shown to all members of a large class simultaneously.

References

BERGEN and CALDWELL. Practical Botany, pp. 15–17.
BERGEN and CALDWELL. Introduction to Botany, pp. 38, 39.

EXERCISE 25

HOW IS EXPOSURE TO LIGHT FAVORED BY LEAF ARRANGEMENT?

Materials. The exercise is preferably worked out as a field trip, but potted plants may be used in part if necessary.

Directions for work. In studying the arrangement of leaves with reference to light, remember that light comes from all parts of the sky as well as directly from the sun's disk. The average direction of light may therefore be taken as approximately vertical, but it must be remembered that much light comes from other parts of the sky as well.

1. Select a vertical stem which is not shaded or crowded by any neighboring stems. This may be found on a small tree or shrub, or a weed, such as ragweed, may be used.

Beginning at the top, note the position of each leaf blade. How many leaf blades face a part of the sky which is within 45° of the vertical? How many of the leaves, when viewed at right angles to the surface of the blade, appear to be shaded by other leaves? What proportion of the whole leaf surface of the stem is so shaded?

2. Select a horizontal stem on either a creeping plant or a nearly horizontal branch of a tree. Note the position of each leaf and its exposure to light. In this case are the leaves distributed all around the stem, as was true of the vertical stem? If not, are they in this case attached to the stem in different positions from the former example, or by what means are they able to assume the new positions? If the previous study (1) has been made on a tree, it is interesting to use for this study (2) another branch on the same tree, making comparisons between them.

3. Examine a vine growing on a wall, as the Boston ivy. Note that in this case the light from one half of the sky is cut off by the wall. The average direction of the light reaching the leaves is therefore oblique.

Supposing the light to come to the leaves at an angle of 45° from the vertical, how large a part of the leaf surface appears

to be in shadow. How much unoccupied wall surface is visible between the leaves. According to your calculations, what per cent efficient is the plant in intercepting the light which comes to the part of the wall occupied by the plant?

4. May leaves be arranged to receive less than the maximum amount of light?

Examine plants of prickly lettuce growing in the bright sunshine. Do the surfaces of the leaves face upwards? What is their characteristic position? What effect would this position have upon the intensity of illumination on the leaf surfaces at noon on a bright summer day?

If the compass plant (*Silphium laciniatum* or *S. integrifolium*) grows in your vicinity, examine it also. Why has it been called the compass plant?

References

BERGEN and CALDWELL. Practical Botany, pp. 55–65.

BERGEN and CALDWELL. Introduction to Botany, pp. 69–77.

Longfellow's "Evangeline," ll. 1216–1221, refers to the compass plant.

EXERCISE 26

HOW DO PLANTS WITHOUT CHLOROPHYLL SECURE THEIR FOOD? A PARASITE AS AN EXAMPLE

Materials. Common dodder (*Cuscuta*), which may be found as a field pest and on wild plants in many parts of the country. Other dependent flowering plants may be substituted if more convenient, but in this case the directions must be suitably modified. Mistletoe, beechdrops, broom rape, pinesap, and cancer-root are examples of parasites; Indian pipe is a saprophyte. The class should study the material in the field if possible.

Directions for work. Describe the general characteristics of the dodder plant, such as its size, color, presence or absence of leaves, and manner of climbing.

What evidences of a dependent habit do you find in the structure, color, etc. of the dodder? What evidences of a parasitic habit in its connection with the host? Cut sections through host and parasite and by a study of these determine whether the parasite penetrates the host or is merely adherent to the outside. What evidence do you see of any effect of the parasite on the host?

References

BERGEN and CALDWELL. Practical Botany, pp. 383, 384.

BERGEN and CALDWELL. Introduction to Botany, pp. 51–53.

EXERCISE 27

A SAPROPHYTE; MOLD AS AN EXAMPLE

Materials. Package of gelatin; petri dishes or glass sauce dishes with plates of glass for covers. Prepare the gelatin for use as directed on the package and pour enough in each dish to cover the bottom an eighth of an inch in depth. Cover with the glass plates. Allow it to stand until the gelatin has set.

Directions for work. Transfer a little material from a moldy object to the surface of the gelatin in the dishes. If possible, plant mold from several sources in different dishes. Set the dishes aside for several days or until some growth appears. Some of the dishes should be placed in the dark. Observe from day to day and make a daily memorandum of the facts observed relative to each culture.

When the mold is well grown make a more careful study, using hand lens or microscope. Determine the following facts regarding the nutrition of the plants:

Is there one kind of mold or several? Do the molds possess chlorophyll? Are they able to manufacture food? Do they grow in the dark as well as in the light, and what does this indicate about the source of their food? Do the molds enter the gelatin or have any connection with it which would indicate a possibility of securing food from the gelatin? Incline one of the dishes and note whether the consistency of the gelatin in the vicinity of the mold patches indicates that the mold is having an effect upon the gelatin. Do these observations prove that the mold feeds upon the gelatin?

Write a description of the mold and an account of your observations upon it, with such inferences as you think are justified by the facts observed.

References

BERGEN and CALDWELL. Practical Botany, pp. 213–216.
BERGEN and CALDWELL. Introduction to Botany, pp. 234–237.

EXERCISE 28

WHAT USE MAY THE PLANT MAKE OF FOOD MATERIALS, SUCH AS STARCH?

Materials. Pieces of green willow about twelve inches long and one-half or three-eighths inch in diameter; quart fruit jar.

Directions for work. Stand the willow branches in the jar in about four inches of water. Place the jar in a sunny window. When roots are beginning to break through the bark near the lower end of the sticks, girdle all of them excepting one by removing a narrow strip of bark all around the stick. Be sure to remove the bark clear to the wood. Some of the pieces may be girdled just above the water level and others at or below the surface of the water.

Watch the further growth of roots above and below the girdle and compare with the uninjured branch. What effect upon the growth of the roots results from interruption of the bark? On the supposition that the bark is the principal path for the transfer of food, what use does the plant appear to be making of food stored in the stem or manufactured by the leaves? To what other similar purposes may food possibly be put in the plant?

References

BERGEN and CALDWELL. Practical Botany, pp. 77–81.
BERGEN and CALDWELL. Introduction to Botany, pp. 43–46.

EXERCISE 29

HOW MAY INSOLUBLE FOODS, AS STARCH, BE MOVED FROM PLACE TO PLACE IN THE PLANT?

Materials. Corn grains which have been soaked twenty-four hours; corn grains which have germinated and grown sprouts an inch long; young corn plants several inches high with the seed grain attached; Fehling's solution; iodine solution.

Directions for work. Crush the soaked grain and boil it in water in a test tube. Pour part of the resulting solution into another tube and add iodine. Is there much starch present? To the remaining liquid add Fehling's solution and bring to boiling. If glucose (a form of sugar) is present, a copper-red or orange color appears and the material which produces the color settles to the bottom later as a precipitate. The amount of sugar may be judged by the amount of precipitate if sufficient Fehling's solution has been added to act on all the sugar. A slight blue color in the solution after the precipitate has settled indicates that a slight excess of Fehling's solution has been used.

Repeat both tests with germinated grains and with the grains which have been separated from young corn plants.

Note the facts discovered in each test. What evidence do you have regarding the gradual disappearance of the starch? What evidence of the presence of sugar when starch is disappearing? If starch can be changed into sugar, would the transportation of this sort of food material be explainable? How?

The experiment may be repeated with other common seeds.

References

BERGEN and CALDWELL. Practical Botany, pp. 78–81.

BERGEN and CALDWELL. Introduction to Botany, pp. 40–43.

EXERCISE 30

DIGESTION OF STARCH

Materials. Starch paste; malt extract; Fehling's solution; iodine solution; funnel; filter paper; test tubes.

To prepare the starch paste, place in a test tube a lump of starch half as large as a grain of corn, add a small amount of water, and boil until all lumps have disappeared and a transparent, slightly milky fluid is obtained. Dilute the starch paste thus obtained with three or four ounces of cold water.

Crush a spoonful of germinated barley grains and soak in one or two ounces of water for an hour or longer. Filter off the water and set it aside as stock malt extract.

Directions for work. To determine whether starch can be changed into sugar experimentally, proceed as follows: Select four large test tubes and label them numbers 1, 2, 3, and 4. Place in each about one inch of the dilute starch paste. To numbers 3 and 4 add about two cubic centimeters each of the malt extract. Set all four aside for at least ten minutes — preferably an hour. At the end of this time treat each tube as directed below and record observations. Remember (Exercise 29) that Fehling's solution gives the test for sugar only after boiling.

What substance do you know by experimental evidence to be present in the original starch paste? What is the evidence?

TUBE	ADD	OBSERVATIONS
1	Iodine solution	
2	Fehling's solution	
3	Iodine solution	
4	Fehling's solution	

What substance is shown to be absent from the original stock of starch paste? What is the evidence?

Was the substance which you found in the dilute starch paste present also after the malt extract had been added? Was any substance present after malt extract was added that was not originally present in the starch paste? If so, how do you account for its presence?

Write a full account of the experiment, giving your explanations of the changes observed and the reasons for your opinions.

NOTE. Some sugar is always present in the malt extract and is carried into tubes 3 and 4 with the malt. The relative amount may be determined with sufficient accuracy if to an inch of water in a fifth tube is added malt extract and Fehling's solution in quantity equal to that placed in tube 4. Upon boiling, a red precipitate is formed, its quantity indicating the amount of sugar present in the malt extract.

Reference

BERGEN and CALDWELL. Introduction to Botany, p. 46.

EXERCISE 31

WHAT PROVISIONS ARE MADE ANNUALLY FOR NEXT YEAR'S GROWTH OF BRANCHES? FOOD STORAGE

Materials. Twigs of any common tree or shrub which has large buds, buckeye, horse-chestnut, and some hickories are best; lilac is common everywhere and is satisfactory; iodine solution; Millon's reagent.

Directions for work. Split a twig and bud lengthwise. Apply iodine to the freshly cut surface of one half. Is there any evidence of the presence of food in the form of starch? Is the quantity relatively great? Microscopic examination of thin cross sections of the stem stained with iodine may aid in estimating the amount of starch present. Is starch principally in the bud or in the stem?

In like manner apply Millon's reagent to the cut surface of the other half of the twig and bud. This reagent produces a red color, after five or ten minutes, if protein is present. However, since the living substance in all cells (protoplasm) is a protein, the red color may not be taken to indicate stored protein food unless the color is pronounced.

What are the facts as you find them regarding the reserve supply of these two classes of foods in the stem and the bud?

Does it appear to you that the amount of reserve food would be sufficient to maintain the spring growth from the buds for a long time, or will the new growth apparently soon depend upon the manufacture of food by the new leaves? As you recall your observations of the opening of buds and the beginning of growth in spring, are the new leaves actually exposed to the light early or late during the spring growth?

Sum up in your notes all your observations of facts which would influence the new growth in the spring.

References

BERGEN and CALDWELL. Practical Botany, pp. 77, 78.
BERGEN and CALDWELL. Introduction to Botany, pp. 43, 44.

EXERCISE 32

PREPARATION FOR NEW GROWTH IN THE STRUCTURE OF THE BUD

Materials. Twigs and buds as in preceding exercise.

Directions for work. Examine a scaly bud in its winter condition to discover what indications of next spring's growth may be found in autumn and how the growing point is protected during the winter.

Pick off the scales one by one, with care to remove the entire scale in each case. Note differences in the scales as you reach the deeper parts of the bud. When the last of the bud scales has been removed, note the central part of the bud, which represents the preparation for next year's growth. Can you distinguish leaves? If so, count them. Can you find a stem? Examine with a hand magnifier to make sure on the above points. If leaves are found, distributed along a short stem, this constitutes a miniature leafy shoot. What changes would need to take place in the spring to transform the contents of the bud into a shoot capable of making food?

Examine another bud with reference to the protection of the growing point from the unfavorable conditions of winter. Compare with a longitudinal section through a bud (Exercise 31). About what is the thickness of the protective layer of bud scales? Do they fit closely or loosely? Would this thickness be sufficient, in your opinion, to keep the center of the bud above freezing temperature during a long period of zero weather? If possible to do so, cut open buds out of doors in severe weather and note whether the interiors of these buds appear to have escaped freezing. Would the bud covering be effective in delaying freezing and thawing?

Consider the need of protection from drying. Is it probable that water would evaporate from an unprotected growing point during cold weather? Does water evaporate from other objects, as from wet clothing, while frozen? Does it seem probable that water would be supplied to the bud by ascending through the stem during very cold weather? Why? Is the layer of scales

thick enough and do they fit closely enough to greatly hinder evaporation of moisture? Examine several kinds of buds for the presence of gummy or varnishlike substances which might assist in making the bud covering impervious to moisture. Compare growing tips which have been exposed to the air for some time with those from freshly opened buds, noting whether the growing point actually wilts or dries more rapidly when the protective covering is removed.

May protection from mechanical injury by the bud scales be of any importance?

Could a structure similar to the young shoot in the center of this bud, but without protecting scales, be called a bud? Under favorable circumstances might it be able to produce a new shoot, as this bud does? Examine a geranium or other house plant, and compare buds.

Write a careful account of your observations and give your opinion regarding the usefulness of the scales for protection from cold, dryness, and mechanical injury. Give reasons for your opinions, distinguishing carefully between observed facts and inferences.

Make a diagrammatic drawing of a longitudinal section through a bud, showing the principal facts of structure.

References

BERGEN and CALDWELL. Practical Botany, pp. 90–92.
BERGEN and CALDWELL. Introduction to Botany, pp. 94–98.

EXERCISE 33

THE OPENING OF A BUD

Materials. Trees and shrubs in the field. During the winter, buds may be caused to open by standing cut branches in water, but the buds do not usually develop completely.

Directions for work. In spring, at the time when buds are about to open, select a conveniently located tree, or several of them, with large buds. Observe the buds each day and make written notes of changes observed, examining the same buds each time. Continue until the shoots are several inches long. A very interesting and valuable record may be secured by photographing the selected buds daily. The camera should be close to the buds in order to secure a large image.

What is the history and the final fate of the scales? When the bud is fully opened, is there left on the twig any mark which shows the former position of the scales? Do the scales on any of the trees examined become more leaflike during the period of observation?

What is the history of the growing shoot during the period of observation? How many inches, or what fraction of an inch, per day does it lengthen when growing most rapidly? Does the number of new leaves increase during this period of rapid growth, or have all the leaves been formed by the time the shoot emerges from the bud? In what way does the new shoot differ from older shoots on the same tree? Are there living leaves on the older parts of the stem at this time?

Enter your daily observations, with dates, in your notebook, and write a careful summary of the important facts connected with the opening of a bud.

References

BERGEN and CALDWELL. Practical Botany, chap. vi.
BERGEN and CALDWELL. Introduction to Botany, chap. vii.

EXERCISE 34

THE HISTORY OF THE GROWTH OF A BRANCH

Materials. Twigs or short branches as used in preceding exercise. This exercise is best carried out in the field, where branches may be examined on the trees.

Directions for work. Examine several branches and determine the limits of last season's growth. This may be readily determined by differences in color and general appearance of the bark. The junction between the part of the twig grown last season and the part a year older is marked by the bud-scale scars (Exercise 33). Aided by the bud-scale scars, identify each year's growth as far back along the branch as it is possible to distinguish these scars. What is the year of growth of the oldest section of the branch the date of which you can positively identify? Is the amount of growth year by year practically uniform? If not, can you suggest possible causes for difference?

Give attention next to the conspicuous and more or less crescent-shaped scars which are distributed along the stem. They are leaf scars, left when the leaves fell and indicating the point of attachment of leaves. Compare with the leafy tips of branches, or in winter with house plants, to secure a clear notion of the relation of leaves to leaf scars. How many leaves were on last season's growth? How many the preceding season? In general, is the number of leaves produced annually rather uniform or does it vary widely? The small scars within the leaf scars show where fibrovascular bundles passed into the leaves.

Reëxamine the stem with reference to character and location of buds. In addition to the large bud at the end of each twig (terminal bud) which was studied in some of the preceding exercises there are usually many buds scattered along the sides of the twigs. These are called lateral buds. What is the position of the lateral buds with reference to the leaf scars? What was their relation to the leaves? Are they formed while the leaves are yet on the branches or after the leaves have fallen? If you have watched the opening of buds in spring (Exercise 33),

have you found that the lateral buds open? If so, what do they produce? On the older parts of the branch which you have been examining are there any evidences of growth from lateral buds? What have the lateral buds produced? Determine, by examination of the twig, when each of these buds began to grow. Do the buds open during their first season; that is, without having spent a winter in the resting condition?

Other well-marked scars are often found on branches. These may be scars left by fruit or flowers, and they vary greatly in size and position in different kinds of trees. Scars due to injuries may be present also.

Draw a line to represent the branch you have been studying and mark the end of each year's growth. Indicate in figures the year in which each section grew. In like manner add the secondary branches and indicate their annual growth.

Set down in your notes all the facts to which your attention has been called in this study or which you have observed independently. Then write a connected story of the growth of the particular branch you have been studying.

References

BERGEN and CALDWELL. Practical Botany, chap. vi.
BERGEN and CALDWELL. Introduction to Botany, chap. vii.

EXERCISE 35

SOME EXAMPLES OF EXTENSIVE STORAGE OF FOODS

Materials. Tubers of potato or Jerusalem artichoke; bulbs of onion or hyacinth; some carrots, parsnips, turnips, sweet potatoes, or radishes; eosin; iodine; Fehling's solution; Millon's reagent.

Directions for work. 1. Cut open a tuber and test several parts of the interior for stored foods, using the tests with which you are familiar from preceding exercises. Does food material appear to be relatively abundant? Is it generally distributed throughout the tuber? What kind of food material appears to be most abundant? In textbooks of human physiology or home economics look up the composition of the potato, noting especially the proportion of proteins and carbohydrates. Do your conclusions correspond to the analysis given? Why are potatoes a valuable article of food for men? What use is made of the stored food by the potato plant?

Tubers are said to be very much thickened stems. Can you prove or disprove this? Examine the exterior of the tuber for such features as you found on stems (Exercise 34). Are there buds present, as indicated by their readiness to grow into new shoots and by budlike structure (Exercises 31, 32)? Can you identify the terminal bud? Is there anything which corresponds to leaves? Review the previous exercises, or the textbook, to refresh your mind regarding the exact position of leaves with relation to buds, and note that as the tuber is underground, any leaves found upon it might differ very much from ordinary foliage leaves.

To determine the location of fibrovascular tissues, cut off a slice of the tuber at the opposite end from the terminal bud and stand the tuber on the cut end in red ink or eosin solution. After twenty-four hours cut cross and longitudinal sections and trace the fibrovascular bundles. Can you trace the fibrovascular bundles out to the structures suspected of being buds?

2. Examine a bulb for stored food as the tuber was examined, using the outline and questions given under 1.

Investigate the structure of the bulb by removing the scales one by one, as you did when you studied the bud. In what respects does the bulb resemble a bud? In what respects does it differ? How does the amount of food stored in the bulb compare with that stored in a bud? Is the food in the bulb stored in the new shoot or in the scales?

3. In a similar manner study one of the enlarged roots. Note that while the enlarged part of the carrot, parsnip, etc. is principally root, yet the upper part bears leaves and is therefore stem. The sweet potato is a root only.

Compare roots such as these with roots of common annual plants, as ragweed, to secure a notion of the comparative enlargement.

References

BERGEN and CALDWELL. Practical Botany, chap. v.
BERGEN and CALDWELL. Introduction to Botany, pp. 87–89.

EXERCISE 36

THE USE MADE OF STORED FOOD

Materials. Mature turnips, carrots, parsnips, or beets.

Directions for work. Plant several turnips or other thickened roots in the garden in the spring, allowing them to grow until they "go to seed." Note the rapidity with which the first leaves and the erect stem are formed, compared with the rate of growth from seed.

When the plants have set seed, dig up one and cut open the root. Has it remained firm? Make the usual food tests. Does it contain as large an amount of food as when planted? Examine several other roots to see whether the facts you find in one are characteristic of all.

In autumn it is usually possible to find in gardens old radishes which have produced seed as well as many younger radishes. It is then possible to make the above study by direct comparison, without growing the plants.

On the basis of the above study do you find that the stored food may be used by plants? If so, for what purpose?

References

BERGEN and CALDWELL. Practical Botany, pp. 33–35.

BERGEN and CALDWELL. Introduction to Botany, pp. 43–46.

EXERCISE 37

HOW DOES THE AMOUNT OF AVAILABLE STORED FOOD AFFECT GROWTH?

Materials. Old potatoes. Potato tubers will not sprout readily soon after being dug. If the exercise is performed in the autumn, the tubers to be used should be some that have been stored for some time, preferably in a cold place.

Directions for work. Cut one of the tubers into two pieces crosswise, split another from end to end, and cut several others into various-sized smaller pieces. Cut several pieces so as to include only one eye and very little food reserve; cut several others with one eye and as much stored food as possible; secure several pieces without eyes, and some pieces with several eyes to the piece. It would add exactness to the experiment if the pieces selected for planting were weighed.

Plant the pieces of tubers in a garden, if the study is made in the spring, or in a box of clean sand in the laboratory. Put a small numbered stick by each piece planted and record in your notebook the descriptions of the pieces.

Make daily memoranda of the growth of the sprouts as soon as they appear above the soil. When it appears evident that no more will come up, dig up all the pieces planted and lay them in a row on the table for inspection. Tabulate the facts as follows:

NUMBER	SIZE OR WEIGHT	NUMBER OF EYES	NUMBER OF SPROUTS	TOTAL LENGTH OF SPROUTS	REMARKS

EXERCISE 37 (*Continued*)

Is every part of the surface of a potato able to give rise to a sprout? What part of the potato is necessary for the production of a sprout? From how small a piece did you succeed in securing growth? Does more than one eye commonly grow when several are present? What is the relation of amount of stored food to vigor and amount of growth?

References

BERGEN and CALDWELL. Practical Botany, pp. 82–85.
BERGEN and CALDWELL. Introduction to Botany, pp. 44–46, 87–89.

EXERCISE 38

FIELD STUDY OF FOOD STORAGE

Materials. Various early spring plants in the field.

Directions for work. In the early spring, when plants are beginning growth, note which ones make a very rapid growth, as shown by the formation of large and numerous leaves within a few days or by very early flowering. Examine the underground parts of these plants and note in how large a proportion of cases you find evidence of food storage.

Tabulate your observations as follows, giving the name of the plant in each case (if known), the kind of food-storage organ (as tuber, bulb, root, etc.), and the relative amount of storage.

NAME	KIND OF ORGAN	RELATIVE AMOUNT OF STORAGE	REMARKS

What do you find to be the relation between storage and early spring growth?

Reference

BERGEN and CALDWELL. Practical Botany, pp. 491, 492.

EXERCISE 39

VEGETATIVE REPRODUCTION BY STOLONS AND RUNNERS

Materials. Blackcap raspberry plants and strawberry plants in place in the garden.

Directions for work. 1. *Stolons.* When the new raspberry canes which come up each spring have become long enough to droop considerably at the ends, bend some of them down so that the tips are in contact with the soil, which should be loosened up somewhat at that point. Fasten each branch down by laying a clod of earth on each one or by pinning down with a forked stick. Examine from time to time, noting how the stem tip establishes connection with the soil and forms a new plant.

In a group of black raspberries such reproduction as the above commonly occurs naturally, and examples may be found without difficulty. Early in the spring the plants that have been thus formed during the preceding season may be separated from the parent plant and transplanted.

Write a full description of the formation of new plants by this method.

2. *Runners.* Examine strawberry plants after the fruiting season is past, which in most parts of the country may be in July. Do you find any tendency to form new plants by the rooting of branches in contact with the soil? Are these branches foliage branches of the usual type, as in the raspberry, or are they special branches having reproduction as their principal office?

Write an account of your observations.

References

BERGEN and CALDWELL. Practical Botany, p. 85.
BERGEN and CALDWELL. Introduction to Botany, p. 90.

EXERCISE 40

REPRODUCTION FROM LEAVES

Materials. Leaves of bryophyllum plant.

Directions for work. Remove several leaves from the plant and lay them on soil or sand. After several weeks a number of small plants will be found growing at the edges of each leaf. When these are well rooted they may be separated from the leaf and transplanted.

Some other leaves, as those of gloxinia and begonia, will reproduce in a similar manner but not so readily as bryophyllum. Begonia leaves occasionally produce small plants while still attached to the plant.

Reference

BERGEN and CALDWELL. Practical Botany, p. 89.

EXERCISE 41

REPRODUCTION FROM ROOTS

Materials. Locust or silver-leaved poplar trees which are sending up "sprouts" at some distance from the parent trees.

Directions for work. Select young sprouts, preferably not over two feet tall, and dig away the earth about their bases until the connection with the parent plant is reached. Do they arise from undoubted roots? Do they arise at the end of a root or along its course? Is there any reason for thinking that they might be able to continue growing if connection with the parent plant were interrupted? Sever the main root between the sprout and the parent plant, carefully replace the earth, and note whether the sprout shows signs of wilting within a few days; or if the study is before growth begins in the spring, note whether the shoot is able to leaf out as others do.

NOTE. A number of other trees and some shrubs reproduce from the roots, especially if the roots are wounded. Sweet potatoes are propagated from the fleshy roots.

References

BERGEN and CALDWELL. Practical Botany, p. 33.
BERGEN and CALDWELL. Introduction to Botany, p. 32.

EXERCISE 42

PROPAGATION BY ROOTS

Materials. Roots of horse-radish.

Directions for work. Cut off the upper ends of the roots, thus removing all stem tissues and buds. Cut the roots into pieces of various sizes. Plant the pieces in soil or sand and keep moist. When signs of growth are seen, dig up the roots and examine them.

Are buds and shoots formed freely by the roots? Are small pieces of roots able to form shoots? What would be the result of breaking up the roots of a horse-radish plant in the soil, as by plowing? Does this assist in explaining why horse-radish is such a persistent weed?

References

BERGEN and CALDWELL. Practical Botany, p. 33.

BERGEN and CALDWELL. Introduction to Botany, p. 32.

EXERCISE 43

PROPAGATION BY SOFTWOOD CUTTINGS

Materials. Make cuttings, or "slips," by cutting off the tips of branches of the geranium with a sharp knife. Each cutting should be about three inches long.

Directions for work. Remove all the leaves except a few of the smallest ones. Make a trench about an inch deep in the sand and stand the cuttings upright in the trench. Fill the trench and press the sand closely about the bases of the cuttings. Moisten the sand well and place the box in the light, but protect the cuttings from the direct rays of the sun for several days. The sand must be kept warm.

After the first week examine every second or third day by lifting one or two cuttings from the box, together with a small amount of sand. This must be done carefully in order to avoid breaking the roots. The sand may be removed gently and the growth of the roots noted.

When the roots are two inches long the sand may be washed from the roots of one or two cuttings to allow of more careful study. From what part of the stem do the roots grow? Do they come from the cut surface or from the sides of the stem? Has the cut healed or changed in any way? Has the leaf surface increased during the experiment? Why was it necessary to remove most of the leaf surface at first?

If any cuttings are unused when the study is completed, they may be transplanted to pots of earth and allowed to grow for some time, after which they may be taken home by the pupils or used to plant the school grounds.

References

BERGEN and CALDWELL. Practical Botany, p. 86.
BERGEN and CALDWELL. Introduction to Botany, p. 90.

EXERCISE 44

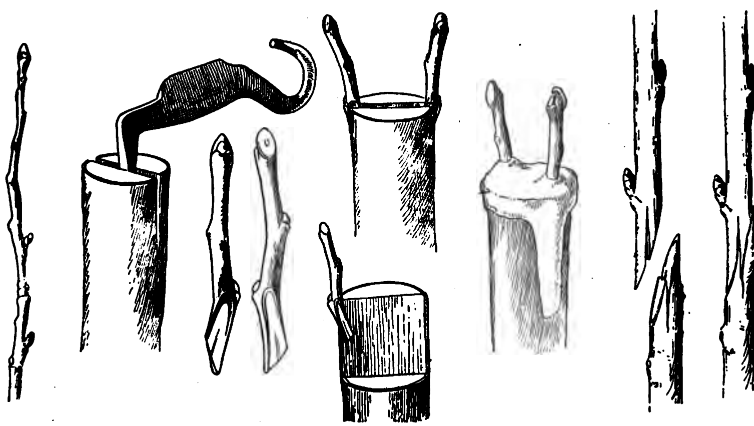
CLEFT GRAFTING

Materials. An apple tree upon the branches of which it is desired to graft another variety; scions of the desired variety; saw; sharp pocket knife; hammer and chisel; grafting wax.

Grafting wax may commonly be purchased from stores which deal in garden and orchard supplies, but it may also be prepared in the laboratory without difficulty. One method given is as follows:

Common rosin	7 parts
Beeswax	2 parts
Beef tallow	1 part

Melt the ingredients together over a slow fire, stirring thoroughly until well mixed. Then pour the melted mass into a pail or tub of



Two Methods of Grafting

cold water. Grease the hands with tallow, and with the hands work the mass together in the water. As soon as it is cool enough to stick together remove it from the water and pull like taffy until it has changed color decidedly and becomes too stiff to work. Roll it into balls and store away for future use, as it will keep indefinitely.

Directions for work. A scion is a cutting from a twig of a tree which is to be used for grafting purposes. The twigs must be cut from the trees while in the dormant condition; that is,

between leaf-fall in autumn and resumption of growth in spring. The best practice is to cut them before the first freeze in autumn and store them in green sawdust in the cellar until they are wanted. They must not be allowed to become dry. The scions should be cut from healthy twigs with firm, well-matured wood. The twigs should not be less than five or six inches long.

Cleft grafting is done in the spring before growth starts. Saw off a branch which is one or two inches in diameter and split the stub down the center with a strong knife. Prepare the scion by cutting it down to four or five inches in length and whittling the lower end to a wedge shape. The wedge should be at least one inch long, tapered evenly on both sides, and smoothly cut.

With a knife or chisel pry open the cleft which has been made in the stub and insert the wedge-shaped end of the scion, placing it so that the bark of one side of the scion will be in contact with the inner bark of the stub (stock). Remove the chisel and allow the cleft to close upon the scion and hold it in position. Melt some wax and daub it over the cut surfaces, sealing them from the air completely.

If the stub of the stock has a diameter greater than two inches, it may be advisable to set two scions, in which case the weaker one should be cut out a year later.

Examine grafts a year or more old and note how growth from the scion has occurred and how healing of the wound has proceeded. Why is it necessary to set the scion exactly in the position directed above? Why not set it in the center of the stub? Make several grafts with the scion in a variety of positions and note results.

NOTE. Top grafting by the method described above may be employed with many trees other than the apple. It is entirely practicable to graft a large number of varieties of apple upon a single stock, thus producing results that are very curious and interesting, though not commercially important.

References

BERGEN and CALDWELL. Practical Botany, pp. 87–89.

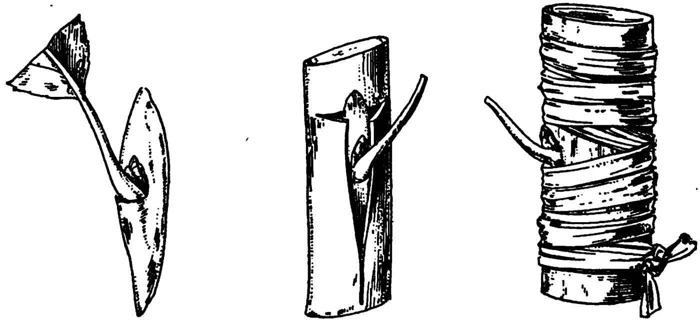
BERGEN and CALDWELL. Introduction to Botany, pp. 91–93.

EXERCISE 45

BUDDING

Materials. Seedling peach trees not over one year old, to be used as the stock; well-grown leafy peach twigs of the season, of some desirable variety; sharp knife; strips of raffia.

Directions for work. Budding is usually done in late summer, the exact time depending upon the latitude. In the southern parts of the country it may be done in June, but in more northern latitudes not before the last week in August. In any case the budding must be done while growth is vigorous.



At a point on the stock two or three inches above the ground make a cut through the bark, but no deeper, and about halfway round the stem. From the center of this cut make another extending downward about an inch. Gently lift the bark with the knife point and slightly turn back the two flaps formed. The bark should peel readily.

Select a leafy twig of the variety which it is proposed to graft upon the stock and cut off a number of leaves, allowing a half inch or more of the petiole to remain attached to the twig (called a "budding stick"). With the knife cut into the twig below the selected bud and continue the cut upward under the bud in such manner as to raise a triangular shaving, with its broader end remaining attached and the bud situated near its middle. Make a crosscut through the bark just above the bud. The bud and its attached triangular piece of bark may

then be peeled from the wood and inserted, pointed end first, under the flaps of bark on the stock. The stub of the leaf petiole will serve as a handle in manipulating the bud. The bud should be pushed down under the flaps of bark until the upper edge of bark attached to the bud abuts against the bark on the stock. Press the graft into good contact with the wood by wrapping with a strip of raffia.

If at the end of ten days the petiole stub below the engrafted bud remains green, it may be supposed that the graft has formed a union with the stock. The raffia should then be removed by cutting it on the side opposite the bud. If budded in the autumn no growth is to be expected before the next spring. The stock should then be cut off just above the bud.

Budding may also be employed in top grafting older trees. Many kinds of trees besides peach are commonly budded. The seedless orange trees, for instance, are budded upon sour orange trees or upon lemon trees.

References

BERGEN and CALDWELL. Practical Botany, pp. 87–89.
BERGEN and CALDWELL. Introduction to Botany, pp. 81–83.

EXERCISE 46

THE PARTS OF A FLOWER

Materials. Any fairly large flower that can be secured in the autumn excepting the composites, such as goldenrod, aster, chrysanthemum, and dandelion. Flowers of house plants, if not "double," may be used.

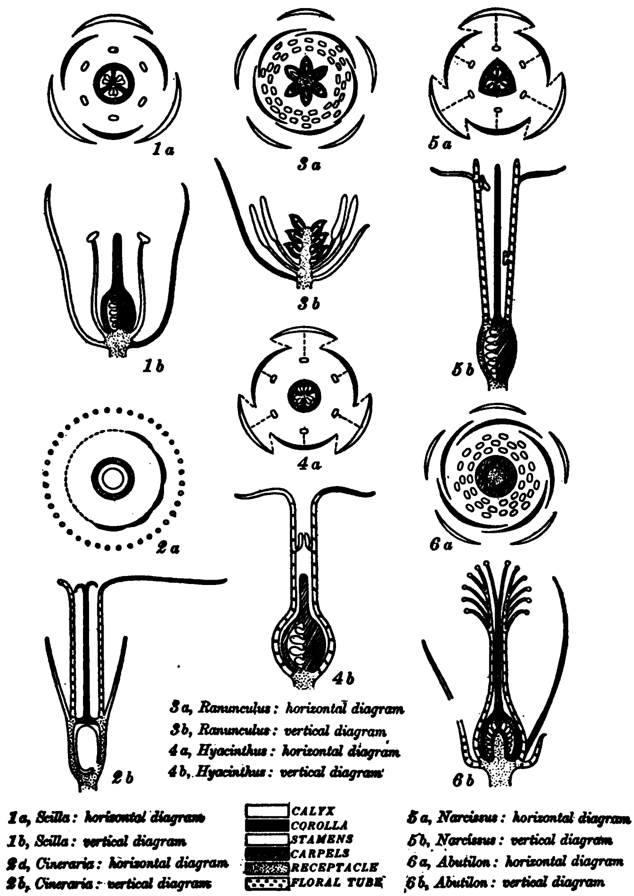
Directions for work. By the aid of the textbook identify sepals, petals, stamens, pistil, receptacle. Identify also the parts of the pistil — ovary, style, stigma. Beginning at the outside of the flower, pick off each of the parts of the flower, noting where it is attached, its relations to the other parts, and its form and color. When you have satisfied yourself that you know the relation of the different parts to each other, make a floral diagram showing an ideal vertical section through the flower and another showing the plan of the flower. These are commonly known as vertical diagrams and horizontal diagrams. In making the horizontal diagrams draw the circle upon which the diagram is built with a compass. Use the same shapes and shading to represent petals, sepals, etc. as are used in the figures. Be careful to make the diagrams symmetrical.

After having completed the study of the first flower, examine several others, making floral diagrams. At least five should be studied.

Compare the series of completed horizontal diagrams. Is the number of sepals the same in all the flowers studied? What are the most common numbers? In the flower first studied are the petals of the same number as the sepals, or a multiple of the same number, or is the number of petals wholly unrelated to the number of sepals? What is the number of stamens, and how does it compare with the number of sepals and petals? Can you detect any numerical plan in the flower?

Study each of the horizontal diagrams in turn with reference to the numerical plan.

Compare the vertical diagrams with reference to the attachment of the several organs of the flower. In the first flower studied are the sepals inserted upon the receptacle? Are the



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petals inserted on the receptacle? If not, where are they inserted; that is, from what part of the flower do they appear to spring? What do you observe about the insertion of the stamens?

Study each of the vertical diagrams in like manner.

References

BERGEN and CALDWELL. Practical Botany, chap. vii.
BERGEN and CALDWELL. Introduction to Botany, chap. ix.

EXERCISE 47

HOW ARE SEEDS AND FRUIT FORMED FROM THE PISTIL?

Materials. Tomato flowers and fruits in all stages of development, from the newly opened flower to the ripe fruit. The small and unimproved varieties, as the cherry tomato, are much to be preferred to the improved garden varieties. Many other fruits, as ground cherry, wild nightshades, lemon, orange, apple, and pear, may be used for this or similar studies.

Directions for work. Make floral diagrams, both vertical and transverse, showing the relative position of all the floral organs. Include a cross section of the ovary in your diagrams or draw it separately.

Arrange the tomato fruits in order of age, judging by relative size and general appearance. By studying them in succession find out what becomes of each of the parts of the flower. Make a series of two or more vertical diagrams showing these facts.

Make cross sections of the fruits in different stages of development and represent in diagrams the changes which take place in the internal parts of the fruits.

Write briefly the story of the development of the fruit from the flower.

Any other plant which bears flowers and fruits at the same time may be used. Evening primrose and the peas and beans are suggested.

References

BERGEN and CALDWELL. Practical Botany, pp. 111–114.
BERGEN and CALDWELL. Introduction to Botany, pp. 130–132.

EXERCISE 48

HOW IS POLLEN CARRIED FROM STAMEN TO STIGMA?

Materials. A variety of wild or garden flowers growing undisturbed; hand magnifier.

Directions for work. This is a field study. If flowers and insects are not abundant at the time this exercise would naturally be taken up, this and several following exercises may be postponed, together with the corresponding parts of the textbook, until a suitable time in the spring of the year. This exercise might appropriately follow Exercise 105.

Select a location where flowers of several kinds are abundant. Visit the place early in the morning and observe the visits of insects to the flowers. Selecting a group of flowers which appear to attract insects in abundance, observe closely the actions of the insects, noting how they enter a flower, how they leave it, and whether they come in contact with pistil and stamens. Does any pollen adhere to the body of the insect? Is there any probability that pollen is transferred from stamen to stigma in the same flower? Does the insect visit flowers of the same kind in succession, or does he go from one kind to another at random? What is the importance of this point? Examine stigmas in flowers that have been visited by insects and try to ascertain whether there is pollen on the stigmas. It would also be of interest to inclose opening buds in paper bags in order to prevent visits of insects, and to note whether pollen is found on stigmas in these cases. So far as you can tell, do the visits of insects result in pollinating the stigmas? Does pollination appear to be accomplished with pollen from the same flower (self-pollination) or with pollen from other flowers (cross-pollination)? How great is the probability that cross-pollination, either with or without self-pollination, occurs in practically all of the flowers visited by insects.

Make a study of such other flowers as may be found in the vicinity, noting for each such facts as are suggested below:

1. Kinds of insects visiting each.
2. Number of individual insects visiting a given cluster in a given number of minutes.

3. Characteristic actions of the insects in visiting each kind of flower.

4. Peculiarities in the form of the flowers which tend to insure pollination.

5. Any characteristics of the flowers which favor cross-pollination rather than self-pollination.

References

BERGEN and CALDWELL. Practical Botany, chap. viii.

BERGEN and CALDWELL. Introduction to Botany, pp. 137–154.

LUBBOCK. Flowers, Fruits, and Leaves, chaps. i and ii. The Macmillan Company.

EXERCISE 49

PREVENTION OF SELF-POLLINATION BY DICHOGAMY

Materials. Flowers in the field, or, if necessary, the flowers may be brought into the laboratory.

Directions for work. By dichogamy is meant the maturing of stamens and stigma in a flower at different times. The maturity of the stamen may be judged by the shedding of the pollen; most stigmas have a moist surface at the time that the pistil is ready for pollination. If the stamens mature first, the pollen will have fallen before the stigma is in a receptive condition; if the stigma matures first, it usually will have been pollinated by pollen from other flowers before the stamens in the same flower have shed their pollen. Obviously, in either case effective self-pollination will be impossible or highly improbable.

Examine all the flowers available and list them below, indicating, by check mark in the proper column, to which of the three classes they belong:

NAME	STAMENS MATURE FIRST	STIGMA MATURES FIRST	BOTH MATURE AT SAME TIME

References

BERGEN and CALDWELL. Practical Botany, pp. 131, 132.

BERGEN and CALDWELL. Introduction to Botany, pp. 152, 153.

LUBBOCK. Flowers, Fruits, and Leaves, chap. ii. The Macmillan Company.

EXERCISE 50

PREVENTION OF LOSS OF POLLEN

Materials. Flowers, in the field or garden.

Directions for work. 1. *Protection from rain.* Pollen grains which are placed in water soon absorb enough water to cause them to burst. Rain may either destroy the pollen or wash it out of the flower. Some plants, but not all, have flowers so constructed that the pollen is not exposed to rain, or the flowers may close in rainy or cloudy weather.

List the kinds studied, and in column A note the sort of protection from rain which you find, or the absence of protection.

2. *Protection from injurious insects.* Many flowers are equipped with devices which exclude such insects as might feed upon the pollen or nectar but are not likely to cross-pollinate the flower. Ants are the most important insects in this class.

The most common protective characters are hairs on the stem or flower stalk, sticky zones on the stems or flowers, narrow corolla tubes, narrow-throated corollas, and inclosure of the stamens by an almost closed corolla. Examine the flowers you have at hand and note the protective devices, if any, in column B.

NAME	A	B

Reference

LUBBOCK. Flowers, Fruits, and Leaves, chap. ii. The Macmillan Company.

EXERCISE 51

CAN POLLEN BE DISTRIBUTED BY WIND?

Materials. Any of the following which may be in flower at the proper season: cornstalks in tassel; pine trees or cedar trees with staminate cones; maple, box elder, willow, poplar, or ash trees in blossom; timothy or other grasses in flower; ragweeds.

Directions for work. Select for study several species if possible. Examine the flowers to identify stamens and pistils. In many species the stamens and pistils do not occur in the same flower, and often not on the same individual. What relation does this have to the prevention of self-pollination?

Note the character of the pollen and its abundance. Is it moist and sticky or dry and powdery? Is it of such character as to be readily carried by the wind? Jar a flower-bearing branch on which you have discovered ripe anthers. Does the pollen fall from the flowers, and is it carried away by the wind?

Do the pistils appear to be well adapted to catch flying pollen? It is suggested that pistils which extend beyond the calyx and corolla, if these are present, and pistils which have long or feathery stigmas would be more likely to intercept flying pollen than pistils of the usual sort.

Is this method of pollination economical or wasteful of pollen? Is the pollen abundant or scanty in amount in the plants studied?

Sum up your entire study in a brief statement of what it has shown you about the possibilities of wind pollination. Compare the wind-pollinated plants and tell what features you find common to most of them. In what respects are their flowers commonly different from those of the insect-pollinated plants?

References

BERGEN and CALDWELL. Practical Botany, p. 120.
BERGEN and CALDWELL. Introduction to Botany, p. 143.

EXERCISE 52

ADVANTAGES FROM DISPERSAL OF SEEDS

Materials. Dandelions in seed.

Directions for work. To appreciate the advantages resulting from dispersal of seeds, study the conditions that would result if seeds were not dispersed. Count the seedlike fruits on a dandelion head or make a close estimate of the number. There is one seed in each fruit. What is the total number of seeds on a head? Estimating on the basis of the number of heads produced by the plant you are examining, as shown by old seed stalks, flower heads, buds, etc., what is the approximate number of seeds produced per dandelion plant? If these seeds were to fall from the plant without being scattered about by the wind, it may be supposed that they would fall within an area of about one square foot. Supposing them to be evenly distributed throughout this area, how many seeds would there be per square inch? How many dandelion plants would there be room for in this area providing no other plants occupied it? How many square inches of the square foot are actually unoccupied by the parent dandelion and other perennial plants? Do you consider that there would be fair opportunity for any considerable number of new dandelion plants to establish themselves under the conditions supposed above?

Now watch dandelion seeds when a strong wind is blowing. How can you prove that seeds are carried? Examine the area within a distance of one or two hundred feet of a patch of dandelions. How much area do you find not occupied by dandelions? How much area do you find not occupied by any perennial plants? How many dandelions might find room within the area over which seeds are known to be distributed from the one patch?

State your opinion regarding the advantage of dispersal as shown by the facts learned in this study.

References

BERGEN and CALDWELL. Practical Botany, pp. 146–151.

BERGEN and CALDWELL. Introduction to Botany, pp. 166–170.

EXERCISE 53

WHAT ADVANTAGES ARE POSSESSED BY PLANTS HAVING WINGED SEEDS OR FRUITS?

Materials. Winged seeds or fruits. Those of the maple, tree-of-heaven (ailanthus), hop tree, box elder, and trumpet creeper are good. Secure as many kinds as possible.

Directions for work. Study the form and structure of the wing and its effect upon dispersal of seeds.

1. *Action of wing.* In the quiet air of the room drop several seeds from as great a height as you can reach, and watch them descend. Do they "fly away"? That is, do the wings cause the seeds to travel to distant parts of the room, or do the seeds alight on the floor at a point almost directly below the point from which they started? If the seeds descend directly, instead of flying away, what is the effect of the wings upon the movement of the seeds.

Estimate the effect of the wings in the following manner. Experiment with the seeds until you have found at least a half dozen that descend at approximately the same speed. Then remove the wings from one half of the seeds in the lot. Time the fall of seeds with and without wings, as suggested below:

Let one of the pupils ascend a step ladder or stand on a table so as to be able to drop the seeds from a point near the ceiling. Both the wingless seeds and the perfect ones should be placed on the palm of the open hand, and all can be dropped simultaneously by turning the hand palm downward. Let another pupil count aloud at about the rate of a clock's ticking. This can be best arranged by having a small clock in the room and actually counting the ticks. Let one pupil begin counting clock ticks while the other drops the seeds at a prearranged signal, as, for example, the fifth count. The remainder of the pupils should note the count at which the seeds start, the count at which the wingless seeds reach the floor, and the count at which the uninjured seeds reach the floor. Which lot of seeds descends more slowly? How much more slowly? What is the real effect of the wing? Is the wing of any advantage, so far as dispersal

is concerned, in quiet air? Is the wing of any advantage, and, if so, what advantage, when the wind is blowing?

Try the above experiments with several kinds of seeds to see whether your conclusions are true of all. Compare several kinds by dropping simultaneously. On the basis of your experiments, what do you conclude to be the advantage of the possession of a wing, and which of the seeds studied is best equipped in this particular? Test your conclusions by observing seeds falling from trees if possible.

2. *Structure of wing.* Examine and describe the wings. Note shape, thickness, width, length, and relative weight. Can you discover anything in the form and structure of different wings that accounts for the peculiarities of their action?

Write a description of the several winged seeds and fruits and illustrate with drawings which show the important features.

References

BERGEN and CALDWELL. Practical Botany, pp. 146–155.
BERGEN and CALDWELL. Introduction to Botany, pp. 166–171.

EXERCISE 54

WHAT ADVANTAGES ARE POSSESSED BY PLANTS HAVING PLUMED SEEDS OR FRUITS?

Materials. Plumed seeds of several sorts. The several kinds of milkweed, dandelion, goldenrod, and thistle are good.

Directions for work. Experiment with the seeds in the quiet air of the classroom, as directed for winged seeds. Measure the difference in rate of descent for seeds with the plume and those from which the plume has been removed. Also allow some of the seeds to descend in the vicinity of an open window through which the wind is blowing, and note the results.

Compare plumed and winged seeds with each other by dropping both at the same time from as high a position as possible, noting relative rate of descent.

Which kind of plumed seed, among those you have tried, appears to have the better equipment for wide dispersal? In comparing winged and plumed seeds, which did you find generally superior with reference to dispersal? Would this necessarily be true of all winged and plumed seeds?

Would the height of the plant on which the seeds were produced be important in connection with dispersal? Would wings and plumes be equally efficient in the case of low plants, such as the dandelion or the thistle?

Illustrate your notes with sketches of several different types of plumes.

References

BERGEN and CALDWELL. Practical Botany, pp. 146–155.

BERGEN and CALDWELL. Introduction to Botany, pp. 166–171.

EXERCISE 55

WHAT ADVANTAGE IN POSSESSING BURS OR STICKERS?

Materials. Cocklebury and beggar-ticks or Spanish needle; any other kinds of "stickers"; spring balance graduated in grams.

Directions for work. 1. *Cocklebur.* Put one of the burs against your sleeve and notice how readily it takes hold. Pull it off, noting how strongly it holds on. By what means does it hold so firmly? Examine the projections with which the surface of the bur is thickly studded. Are they simple straight spines, like pins, as they at first seem? What peculiarity of their shape enables them to hold? To measure the strength of one of these spines, attach a thread or light cord to the spring balance and tie a loop in the free end of the thread. Hook one of the spines into this loop and pull on the spring balance until the spine breaks or lets go of the thread. What was the maximum amount registered by the balance before the spine failed? Repeat with several other spines. What is the average strength with which the spines are able to hold fast?

2. *Beggar-ticks.* Thrust the points of the beggar-tick into the cloth of a garment, noting the relative amount of force needed to insert the points and to withdraw them. Do they seem to hold effectively? Examine the spines of an uninjured beggar-tick with a magnifier to find out what peculiarity of structure enables it to hold fast. It is sometimes noted that after beggar-ticks have been adhering to the clothing for some time the points come through on the inside, though they apparently did not do so at first. Can you find anything in their structure that would favor a gradually deeper penetration?

3. *Comparison with other burs.* Make a rapid study of other burs which are available, noting resemblance to the two types studied above and apparent effectiveness of their equipment.

4. *Comparison with other seeds.* Burs commonly become entangled in the coats of grazing animals in the autumn. How long would they probably remain attached to the animal? In the case of domestic animals, how far might it reasonably be supposed that they might be carried in the interval? How far

might burs have been carried in former times by such animals as the deer and buffalo?

Compare wind-carried seeds and animal-carried seeds of the type of the burs with regard to the following points:

1. Which sort of equipment is more sure to secure the dispersal of almost all the seeds on the plant?

2. Which sort of equipment is likely to secure the carrying of at least a few seeds to the greatest distance?

How do you account for the fact that strange weeds are often found in the vicinity of wool-cleaning establishments?

References

BERGEN and CALDWELL. Practical Botany, pp. 146–155.
BERGEN and CALDWELL. Introduction to Botany, pp. 166–171.

EXERCISE 56

DISPERSAL OF SEEDS OF FLESHY FRUITS

Materials. Fleshy, edible fruits of several kinds, such as apple, pear, raspberry, strawberry, mulberry, and many fruits of wild plants.

Directions for work. Seeds of fleshy fruits are commonly distributed by being eaten along with the pulp and later voided uninjured from the body of the animal. Birds are particularly notable as distributors of seeds in this manner.

What are the features of the fruits you are studying which might attract the attention of animals and cause them to eat the fruit? Note color, odor, and flavor.

What characteristics, such as small size of the seeds and intimate relation to pulp, make it extremely probable that the seeds will be swallowed along with the pulp?

What characteristics of the seeds make it appear improbable that any large proportion will be destroyed by mastication, by grinding in the gizzards of birds, or by the action of the digestive juices?

Make observations in the field to determine which fruits are readily eaten by birds. Find out also whether any plants of these sorts may be found growing in places where their presence is difficult to explain except on the supposition that seeds are carried by birds. Look especially for plants growing in the forks of trees or in knotholes, on thatched roofs and on old stacks of decaying straw or hay, and along fences or other places where birds are accustomed to perch.

From your observation, do you find that this is a successful means of dispersal?

References

BERGEN and CALDWELL. Practical Botany, pp. 146–155.

BERGEN and CALDWELL. Introduction to Botany, pp. 166–171.

EXERCISE 57

PRODUCTION OF A PLANT FROM A SEED

Materials. Unroasted peanuts; three-inch paraffined paper plant pots; clean sawdust or sand.

Directions for work. Let each pupil fill one of the pots with sawdust or sand which has been thoroughly wet. Plant several seeds in each one, and label the pot for proper identification. Set the pots aside in a dark place until the young plants begin to appear above the surface of the ground. Plant other seeds at intervals during the progress of the experiment in order to assure having a few plants in early stages for comparison at all times. Keep a record of the growth of the young plants by making drawings daily, or at shorter intervals if growth is rapid. When the young plants are erect and the first pair of foliage leaves are well grown, dig up several of them and make a drawing showing all parts, including the roots. Carefully label all the parts of the young plant, using the textbook to ascertain the proper names.

Dig up some of the seeds that were planted later in order to secure stages in the development of the plants before they have come up. Complete your series of sketches. Using your drawings as memoranda, write a connected story of the development of a young plant from a seed.

References

BERGEN and CALDWELL. Practical Botany, pp. 136–145.

BERGEN and CALDWELL. Introduction to Botany, pp. 156–166.

EXERCISE 58

STRUCTURE OF A SEED

Materials. Seeds of bean or peanut; blotting paper or filter paper; dish with cover.

Directions for work. Soak some seeds in water for twenty-four hours. Remove the seed coatings from the seeds and attempt to find in the seeds the parts that were recognized in the seedling plant. Do you find the cotyledons? Describe them. Look for the hypocotyl; for the plumule. Examine the plumule with a magnifier or with the low power of the microscope to determine whether the first pair of leaves is already present in the plumule.

When you have satisfied yourself that you have identified in the seed the part from which each of the organs of the young plant develops, make a diagram representing an ideal vertical section through the seed from end to end, showing the hypocotyl, plumule, and cotyledons in proper relation to each other.

References

BERGEN and CALDWELL. Practical Botany, pp. 136–137.
BERGEN and CALDWELL. Introduction to Botany, pp. 156–160.

EXERCISE 59

COMPARISON OF SEEDS AND SEEDLINGS

Materials. Seeds and seedlings of as many as possible of the following, and any other seedlings that may be readily secured: pea; castor bean; pumpkin or winter squash.

Directions for work. Compare these seeds and seedlings with each other and with the bean or peanut, noting differences.

The principal differences noted will be that the pea cotyledons are not raised above the ground; the cotyledons of the castor bean are not stored with food materials and become effective working leaves; and in the pumpkin, though the food is stored in the cotyledons, they become large and remain long on the plant, while the plumule is very slow in developing.

References

BERGEN and CALDWELL. Practical Botany, pp. 141–142.
BERGEN and CALDWELL. Introduction to Botany, p. 164.

EXERCISE 60

THE COTYLEDONS

Materials. Young plants and seeds as used in the preceding exercise, in various stages of growth; iodine solution.

Directions for work. It will be found that it is frequently stated that the cotyledons are in fact leaves. What facts can you discover that appear to confirm or to dispute this statement? Study several kinds of seedlings. Do the cotyledons have either of the types of arrangement that you have found to be characteristic of the arrangements of leaves on a stem? Are there buds in the positions where you should expect to find buds if the cotyledons are in reality leaves? Do the cotyledons of any plants studied perform the work of leaves?

What special work do cotyledons, or at least some of them, perform that is different from the usual work of leaves? Examine a series of cotyledons from a bean or a peanut plant. Note any changes in the plumpness and apparent volume of the cotyledons as they grow older. Break open the cotyledons and test the interiors for starch. What differences in this particular do you find between older and younger cotyledons? If you can find some plants that are old enough so that the cotyledons are about to fall off, include them in the test, or let some of the plants grow and watch the fate of the cotyledons. What does your study indicate as to the office which the cotyledons are performing?

References

BERGEN and CALDWELL. Practical Botany, pp. 142–144.
BERGEN and CALDWELL. Introduction to Botany, pp. 158–165.

EXERCISE 61

A MONOCOTYLEDONOUS SEED

Materials. Seeds of corn which have been soaked for at least twenty-four hours, and some which have been germinated on blotting paper.

Directions for work. Examine the germinated seeds to identify the plumule and the hypocotyl and root. Examine one of the soaked seeds, and by comparison with the germinated seed locate the general position of the plumule and the hypocotyl. Then cut the seed in two lengthwise through the center so as to split the young plant (embryo) from end to end. This can best be done by making the first cut a little to one side of the center and then carefully shaving off the cut surface until the growing points are properly exposed. By the aid of illustrations identify the cotyledon ("Practical Botany," Figs. 128, 129).

In this case does the cotyledon come aboveground? Is the food stored in the cotyledon or outside of it? What office does the cotyledon serve?

References

BERGEN and CALDWELL. Practical Botany, p. 137, Figs. 127–129.
BERGEN and CALDWELL. Introduction to Botany, p. 158, Fig. 143.

EXERCISE 62

WHAT IS THE EFFECT OF DIFFERENT TEMPERATURES ON GERMINATION?

Materials. Pea seeds; filter or blotting paper; dishes with covers.

Directions for work. Soak all the seeds for twenty-four hours. Divide the seeds into four or five lots and place each lot on wet filter paper or blotting paper in a covered dish. Do not use more seeds than will lie on the bottom of the dish without crowding. Put one of the dishes in the coolest place available but not where the seeds will freeze. Put another dish in the warmest place available but not where the temperature will rise to the boiling point. For the other dishes select places at intermediate temperatures. It is desirable that the temperatures at the various situations be as constant as possible, and the average at each place should be obtained with a thermometer. However, if it is not possible to secure uniform temperatures, the results will be instructive, though not so exact. If it is found that there is considerable variation of temperature, it may be better to plant all of the seeds in sand or sawdust, since the temperature in these substances will vary less than in the air. A thermometer inserted in the soil among the seeds will give the temperature, and readings may be taken several times each day.

If the seeds are placed in dishes it will be well to darken them, since no doubt at least some of the seeds will be placed in a dark place and the results will be fairly comparable only if all are equally darkened.

At the end of four or five days examine each lot of seeds and note how many are sprouted, how many have not germinated, the relative length of the sprouts, and the general appearance of the seedlings. Record the observations in the table on page 78 and write a full description of your experiment, giving all details that might in any way affect the results. What are your conclusions about the effect of different temperatures within the range of temperatures used?

EXERCISE 62 (*Continued*)

NUMBER OF SEEDS	NUMBER GERMINATED	PER CENT GERMINATED	AMOUNT OF GROWTH AND GENERAL CONDITION

References

BERGEN and CALDWELL. Practical Botany, pp. 139, 140.
BERGEN and CALDWELL. Introduction to Botany, p. 161.

EXERCISE 63

WHAT IS THE EFFECT OF GRAVITY ON THE GROWTH OF ROOT AND STEM?

Materials. Pea seedlings an inch in length; sawdust; drinking-glass with sloping sides.

Directions for work. Place the seedlings in the drinking-glass in various positions, so that some of them have root and stem horizontal, others have the stem downward and the root tip upward, and others are in various oblique positions. Place them against the glass and pack wet sawdust in the glass so as to hold them in position and keep them moist. Place the experiment in the dark. Observe later in the day and for several successive days, making observations through the glass. Later, when the roots and stems have made considerable growth, the plants may be removed from the sawdust for more exact study. What direction have the root tips taken? Has the direction been influenced by the position in which you placed the plants? How has the stem reacted in this experiment? What reasons do you have for believing that it is gravity which controls the direction of growth?

It is possible to secure boxes with glass sides, made especially for this experiment, and they are very satisfactory. It may also be performed, if the materials are at hand, in the following manner: Wrap a piece of sheet cork about three by six inches in size with blotting paper. Pin the seedlings in contact with it in the positions desired and stand the cork upright with the lower end of the blotting paper in water. Cover the whole to prevent evaporation and to exclude light.

EXERCISE 64

HOW DO STEMS AND LEAVES REACT TO LIGHT?

Materials. Seedlings of pea, bean, peanut, or any other seedlings available. Older plants may also be used.

Directions for work. Place the seedlings in a small box which is tight enough to exclude light except for a small opening on one side at about the level of the leaves of the seedlings to be used. Note the position of the stem and principal leaves of the plants and make a memorandum of the facts. Place the inclosing box as near to the window as possible, with the opening toward the window.

Make daily observations on the plant for several days, noting any change of position of the leaves and stem with relation to the light. What position does the stem assume with relation to the direction of incoming light? Is this equally true of the older parts of the stem as well as of the newer parts? What position do the leaves assume with reference to the light which reaches them? Is there any difference in the action of old and young leaves?

Reverse the position of the plant; that is, rotate it through 180 degrees, so that the side which was formerly toward the light is turned away from it but the plant remains standing at the same place. How do leaf and stem react at this time?

Is the position assumed by the leaves such as secures the best exposure to the light entering the opening?

References

BERGEN and CALDWELL. Practical Botany, pp. 56, 57, 64, 65.

BERGEN and CALDWELL. Introduction to Botany, pp. 72–76.

EXERCISE 65

RESPONSE TO TOUCH

Materials. Small plants of the sort known as "sensitive plants" (*Mimosa pudica*). These are often kept in homes and conservatories as curiosities. They may be readily grown from seed.

Directions for work. The plant will react most satisfactorily when standing in good light. It should be placed in a window some time before it is to be used, in order that it may have time to recover from the disturbance occasioned by moving it, and it is well to cover it with a glass bell jar to protect it from accidental disturbance before time for the experiment.

Tap one of the leaflets lightly with a pencil. What action follows? Repeat the tap, but somewhat more vigorously. Is the reaction in any degree proportioned to the strength of the stimulus?

Pinch a terminal leaflet on one of the leaves with the forceps or the finger nails, using care not to shake the entire leaf. Does the stimulus instantaneously affect the whole leaf, or is it propagated from the place first affected to other parts of the leaf? What evidence do you have upon which you base your conclusion? Describe in detail what happens in this experiment, including the time intervals concerned, repeating the trial with another leaf, if necessary, to secure data.

Do the leaves recover their original condition after a period of rest? About how long does recovery require? Are they able to respond again after recovery? Is the second response apparently equal to and like the first response?

References

BERGEN and CALDWELL. Practical Botany, pp. 388–389.

BERGEN and CALDWELL. Introduction to Botany, p. 22.

EXERCISE 66

RESPONSE OF TENDRILS

Materials. Pea plants with tendrils, or other tendril-bearing plants.

Directions for work. Select vigorous plants in apparent good condition. Stroke a tendril gently with a pencil, being careful that it shall be touched only on one side. Repeat with several other tendrils. Make careful note of the position and curvature of the tendril and observe it repeatedly for several minutes, making memorandum of the time and the curvature of the tendril at each observation. Does the stimulus of contact produce any curvature? If so, to which side does the tendril curve, and is this curvature permanent?

Thrust a wire or other slender object into the soil and bend it so that it is in contact with one of the tendrils near its tip. Allow the wire to remain in this position, so that in this case the contact with the tendril is permanent, instead of temporary as in the previous trial. Repeat with several other tendrils. Does the tendril curve? Is the curvature permanent? Does the curvature become greater in amount than in the previous trial? Does the tendril finally take hold of the object as you are used to seeing tendrils attached?

In writing your notes discuss both parts of the exercise and write a clear account of how a tendril takes hold of a support.

References

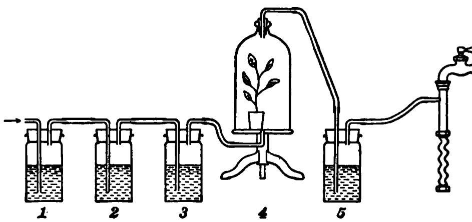
BERGEN and CALDWELL. Practical Botany, pp. 62–64.
BERGEN and CALDWELL. Introduction to Botany, pp. 74, 75.

EXERCISE 67

RESPIRATION

Materials. Small potted plant or germinating seeds; four 6-ounce, wide-mouthed bottles with two-hole rubber stoppers; limewater; caustic-soda solution; respiration chamber, arranged with a bell-jar and air-pump platform; filter pump; glass and rubber tubing. Assemble apparatus as shown in the illustration.

Directions for work. With the apparatus assembled as illustrated, place the plant or seeds in the respiration chamber (4) and some caustic-soda solution in the first and second bottles (1 and 2). Close all bottles and the respiration chamber tightly and start the filter pump. If air does not bubble through the soda solutions, there must be leaks in some of the connections. Go over the whole train and tighten up all parts until air comes through steadily, as indicated by the bubbles in the bottles. Wire the joints between rubber and glass tubing if necessary.



After air has been flowing steadily for several minutes place limewater in bottles 3 and 5. Make sure again that the air passes through the whole train of bottles. If a green plant is used, darken the chamber containing it in order to prevent photosynthesis, else the results of respiration and photosynthesis may not be distinguishable. Bottles 1 and 2 should remove the carbon dioxide from the incoming air, and bottle 3 show whether this has been accomplished; bottle 5 will show whether there is any carbon dioxide in the outgoing air.

Does a plant give off carbon dioxide?

References

BERGEN and CALDWELL. Practical Botany, pp. 19, 76.

BERGEN and CALDWELL. Introduction to Botany, pp. 46–47.

EXERCISE 68

HOW MUCH FORCE DOES THE WIND EXERT AGAINST A TREE?

Materials. A small tree one or two inches in diameter near the ground; ax; rope; heavy spring balance. Select a tree which is not valuable, as it will be destroyed by the experiment.

Directions for work. On a windy day cut the trunk nearly through close to the ground, beginning on the side toward the wind, so that the remaining bark and wood will act as a hinge. Do not allow the tree to fall. Tie a rope to the trunk as near the center of the crown as possible. Attach a spring balance to the rope and support the tree against the force of the wind by pulling on the spring balance. It will be necessary for someone to steady the tree at the same time so that it cannot fall laterally.

How many pounds force does the wind exert, tending to overthrow the tree? How was this force resisted by the uninjured tree? Attach the spring balance to the trunk one or two feet above the ground and note the pull necessary to keep the tree in an upright position. How great strain does the trunk sustain at this point?

Based on your experiment, estimate the pressure of the wind against any large tree in the vicinity, supposing the wind to have the same velocity as it had at the time of the experiment. This estimate will necessarily be only a very rough approximation, but it should give you some idea of the stress to which large trees are subject in time of storm.

EXERCISE 69

DOES THE BARK ASSIST IN STRENGTHENING THE STEM?

Materials. A dozen straight branches of willow, or other available tree, not over one-half inch in diameter, all of the same diameter and as nearly alike in all particulars as possible; small bucket and sand; balances.

Directions for work. Select eight or ten of the branches and divide them into two lots. Peel the bark from one lot, but do not injure the remainder. Support one of the sticks across two chairs which are two feet apart. Attach the bucket to the stick midway between the chairs and add sand until the stick breaks or gives way in some manner. Weigh the bucket and sand to determine the force applied at instant of failure, and record the weight below. Do the same with each stick.

What is the average breaking force for those with bark? For those without? Can you determine by examination of the broken sticks how the bark gave strength?

BRANCHES WITH BARK, BREAKING FORCE	BRANCHES WITHOUT BARK, BREAKING FORCE
Average	Average

EXERCISE 70

TENSILE STRENGTH OF BARK

Materials. Strips of bark from the branches peeled in the preceding exercise, as well as strips of fresh bark from other kinds of trees.

Directions for work. Cut the bark into strips of uniform width. Clamp one end of a strip in a vise and attach a spring balance to the other end by means of a small portable vise, as a wooden cabinet-maker's clamp. Pull upon the spring balance until the strip of bark tears, noting the reading of the balance at the time the bark gives way. Repeat with several pieces of bark of the same kind in order to get an average result. Secure similar data for bark from other species of trees.

Does the tensile strength of bark appear to you to be relatively great? Is there any marked difference in bark from various kinds of plants? Do you know of any textile or cordage fibers that are secured from bark, and, if so, what are they? What materials are manufactured from them?

References

BERGEN and CALDWELL. Practical Botany, p. 47.
BERGEN and CALDWELL. Introduction to Botany, p. 65.

EXERCISE 71

COMPETITION BETWEEN BRANCHES, AND SELF-PRUNING

Materials. Several groups of young trees growing close together. The trees should be from ten to twenty-five feet high and must stand close enough to allow the tops to crowd each other a little.

Directions for work. Examine the group of trees from the outside. It will doubtless be found that they are clothed with leafy branches almost to the ground. Enter the group and look for the living, leafy branches. What part of the trunk is bearing living branches? Why are there none on other parts of the trunk? Were there ever branches lower down? If so, what has happened to them? Do the dead branches remain on the tree for many years? Which fall earlier, the large or the small branches? By studying trees in different situations find out whether the branches die while smaller on trees that are in crowded situations or on those in open places, and which of these situations favors the production of trees with straight, smooth trunks. Which would finally be most suitable for poles and lumber?

Study the relation of branches to knots in the wood. If it is allowable to cut down one of the trees, do so, selecting a tree that has a number of good-sized dead branches or branch stubs and some living branches. Cut sections of the trunk including such branches as mentioned above. Take the pieces to the laboratory and split or saw them lengthwise through the branches. Study the direction of the wood fibers in relation to the living branch. Try to imagine how the grain would run in a plain-sawed board taken from such a part of the tree, and compare with knotty lumber. Would the boards sawed from a tree trunk in the vicinity of the base of a living branch be straight-grained or cross-grained? Would any knot that was found in such a board be a loose knot or a solid one? In like manner examine the surface split through a dead branch. Note particularly the annual layers of wood in the vicinity of the dead branch. How many years ago did the branch die? Are the layers of wood formed since then united with the wood of

the branch? If this branch were buried deeply by the farther growth of the tree and boards were sawed from this part of the trunk, would the resultant knots be loose or solid? What, then, is the origin of knotholes in boards?

If trees are planted with the intention of producing lumber, should they be planted close together or far apart? What advantages would accrue, in the amount and quality of the product, by the method you suggest? How would you decide, in looking over a grove, whether the trees had been planted at the right distance apart?

References

BERGEN and CALDWELL. Practical Botany, pp. 66, 67.
BERGEN and CALDWELL. Introduction to Botany, pp. 77–79.

EXERCISE 72

IN WHAT MANNER ARE WOUNDS IN TREES HEALED?

Materials. Shade and orchard trees with dead branches and accidental injuries.

Directions for work. Examine shade trees or neglected fruit trees on which branches have died or broken and note the growth of adjacent tissues over the wound. If possible, collect pieces of wood showing all stages in the closing of a wound, from the early condition, such as is represented in the slight thickening about the base of a newly killed branch, to those cases in which the opening is completely closed on the outside. Split these pieces through the healing wound and describe the process by which the wound is closed. Selecting a wound that appears to be completely healed, note the original diameter of the wound and the number of years required to close it. Note also whether the wound is completely healed or whether there is inclosed within it any partly decayed wood, which may be infected with wood-rotting fungi and thus serve as a source of infection for the heartwood of the tree. Do large or small wounds heal the more perfectly?

Examine trees from which large branches have been removed or which have been injured by the removal of relatively large areas of bark, as street trees which have been gnawed by horses. Do any of the wounds appear to be too large to be repaired by natural processes before the wood of the trunk has seriously decayed? So far as you can determine by superficial examination, how wide an area may be successfully healed by natural processes? Would painting over the exposed wood with disinfectant substances assist in any way? (Note that different kinds of trees may differ widely in respect to ability to survive injuries.)

Visit an orchard which has been "trimmed" within the last few years. Note whether the cut surfaces are being healed without decay. If possible, find cases in which the stub has been left too long, thus hindering closure of the wound, and other cases in which it has been cut too close to the trunk, thus

making an unnecessarily large wound. Decide upon the proper point to cut a branch which is to be removed.

If there are trees in the vicinity which have been treated by a skilled tree surgeon, visit them and study both his methods and the evidences of their success.

References

BERGEN and CALDWELL. Practical Botany, p. 53.
BERGEN and CALDWELL. Introduction to Botany, p. 105.

EXERCISE 73

WHAT PRECAUTIONS ARE NECESSARY IN TRANSPLANTING YOUNG PLANTS?

Materials. A tray of earth with seedlings of tomato, cabbage, or other small plants; a second tray with earth to which seedlings may be transplanted. Both trays must have holes for drainage.

Directions for work. Transplant groups of seedlings as directed below, using great care. Young seedlings are very delicate.

Group A. Lift out a clump of dirt containing a number of seedlings. Gently loosen the dirt from the roots and transfer each plant quickly to a hole in the earth in the second tray. These holes may be made by use of a pointed stick. Press the earth firmly about the roots. Reject all small or weak plants.

Group B. Transplant as directed for Group A.

Group C. Handle same as Group A with the exception that the roots are to be exposed to the air several minutes. Record the time of exposure.

Group D. Handle same as Group A except that the ground is not to be pressed about the roots more than necessary to keep the plants in position.

Group E. Transplant carefully in all respects, but bruise the stem of each plant slightly by pinching it.

Group F. Allow a certain number of plants to remain in the original tray undisturbed. Water them and care for them just as you do for those that have been transplanted.

Cover all plants with newspaper except Groups B and F. Set them in a light place and water freely for several days. The newspaper should protect those which are covered from excessive transpiration. After several days the paper may be removed. At the end of a week compare the groups. What do you learn from each group?

Write careful directions for transplanting, emphasizing the points you have found to be important.

Watch the plants for several weeks, and by comparing Group F with the other groups try to determine whether transplanting is necessarily harmful to plants.

EXERCISE 74

TRANSPLANTING TREES OR SHRUBS

Materials. Small trees, not over six feet tall, or shrubs of any kind available. Materials may be purchased, but it is as well to find wild trees or shrubs that may be dug up and transplanted to the school grounds. The work should be done in the spring before the buds start.

Directions for work. Dig up the shrubs or trees with care to secure rather long, uninjured roots. Are you able to secure the whole root system? Protect the roots from the air and sun while the plants are taken to their new location.

At the point where each plant is to be placed dig a hole at least two feet in diameter and deep enough to set the plant slightly deeper than it was originally. With a sharp knife trim off any broken or diseased roots and set the plant in the hole. Spread out the roots in their natural position and let one member of the class hold the plant in position while others fill in the earth about the roots. Pack the earth firmly.

Prune the top with reference to (1) the form which you wish the plant to have in the future and (2) the necessity of reducing the leaf surface to correspond with the reduced roots. In the case of a shrub it is common to cut back all the branches to a common height. A tree is pruned so as to favor retaining a single central stem. Any tendency to fork should be corrected by removing one of the branches at that point. Small branches which will later be overshadowed and killed by more vigorous ones should be removed as well as all lower branches which will later be objectionable. Each of the remaining branches should be shortened by cutting at a point just beyond a vigorous lateral bud.

Soak the soil about the roots with water occasionally. Loosen up the top soil if it shows any tendency to become hard and caked.

Observe the growth of the transplants from time to time during the spring. Report upon the success or failure of the attempt at transplanting, and try to account for any failure noted.

EXERCISE 75

WHAT ARE THE SIZE, SHAPE, MOTION, AND GENERAL APPEARANCE OF BACTERIA?

Materials. Prepare materials for study of bacteria several days before they will be needed. Place a handful of chopped hay in a drinking-glass and cover with water. Place several beans in another glass and add water sufficient to soak the beans and half submerge them. Cover both glasses to prevent evaporation and stand in a warm place. Microscopes are necessary.

Directions for work. Transfer to a glass slide a small bit of the scum from the water in which the hay has been soaking. Examine with the high power of the microscope.

The bacteria appear as very small and almost transparent bodies, which may be stationary or in motion. It is probable that several kinds of bacteria will be present in the scum. The kind which is commonly most abundant is rod-shaped and several times as long as wide. Others may be spherical or spiral.

Try to find bacteria representing all three forms (see text-book). The size of the bacteria cannot be measured without special instruments, but they may be compared with each other and with other objects which pupils have previously viewed in the microscope; or a small object, as a hair, may be introduced for comparison.

In studying the movements of bacteria it must be remembered that if all the bacteria in the field of view move together in one direction, it is due to currents of water rather than to any proper bacterial movement. Also, the bacteria may exhibit an interesting dancing movement, called the Brownian motion, which is exhibited by any small particles suspended in a liquid quite independently of whether the particles are living. Certain kinds of bacteria exhibit a relatively rapid independent motion through the water, commonly proceeding in a straight line until coming in contact with some other object.

Describe carefully each of the several kinds of bacteria found as to shape, relative size, rate and character of motion, and whether the individuals occur in chains or masses, or free.

EXERCISE 75 (*Continued*)

Examine some of the larger ones carefully and observe them for some time to discover, if possible, evidences of division.

Repeat the study with materials taken from the decaying beans. Also examine in like manner any other decaying materials found, but do not write notes except on the new facts discovered.

References

BERGEN and CALDWELL. Practical Botany, pp. 161–164.
BERGEN and CALDWELL. Introduction to Botany, pp. 199, 200.

EXERCISE 76

TO STUDY THE GROWTH AND DISTRIBUTION OF BACTERIA

Materials. Prepare a growth medium for bacteria by one of the following methods. The first method is preferable, but the materials may not be available.

Directions for work. 1. Secure as many petri dishes as will be needed for the solution of the problems which are chosen from the list on pages 96–97. Sterilize the dishes by heating in a steam sterilizer for twenty minutes on each of three days, or by heating one hour in a dry-air sterilizer to a temperature sufficient to slightly scorch cotton (150° C.). The latter method is preferable. Secure from the nearest bacteriological laboratory as many tubes of sterile nutrient agar as you have petri dishes. Heat some of the tubes in boiling water until the agar is melted, when the temperature may fall to about 45° C., which will be sufficient to keep the agar in liquid condition as long as necessary. Pour the contents of each tube into a petri dish, cover, and set aside to cool. Reserve the remainder of the tubes for use as directed below. Using gummed labels, number each dish and tube used.

Great care must be taken in the above operations not to allow bacteria to enter the agar either from the air or from any other source. The petri dishes should be covered before the last sterilization, and the covers should not be removed except as directed in performing the experiments. The agar may be poured into the dishes by lifting the cover on one side and inserting the end of the test tube.

2. In case the agar tubes mentioned above cannot be secured, slices of potato may be substituted in the solution of certain problems. Boil a potato the diameter of which is not greater than that of a petri dish, boiling for ten or fifteen minutes to partly sterilize the surface. Cut into thin slices and place one in each petri dish. Sterilize in steam as directed above. Sterilization should be repeated once or twice.

3. Certain of the problems suggested below may be solved by the use of sterilized milk as a medium for the growth of

bacteria. (For detailed directions see Caldwell and Eikenberry, "Laboratory Manual for Work in General Science," Rev. Ed., Exercise 43.)

A substitute for petri dishes may be contrived by inverting a glass sauce dish over a smaller one, but any substitute is unsatisfactory. At least a few petri dishes should be a part of the equipment of every laboratory. A steam sterilizer may be contrived by supporting the dishes above boiling water in a covered pail, but it is impossible to insure that the material will at all times be surrounded by steam at 100° C. A small steam sterilizer is preferable. One or two of the sterilized agar plates should be retained as checks.

PROBLEMS

1. Are there bacteria in the air? Expose one or more of the dishes to the air by uncovering for a measured length of time, as twenty minutes. Replace the cover. Watch for the appearance of colonies of bacteria in two or three days. If dishes are uncovered in different parts of the building, a rough measure of the abundance of bacteria may be secured.

2. Are bacteria present on one's person, as on the hands? Draw the fingers lightly across the surface of the agar in a dish. Observe later for the development of colonies of bacteria. (The agar must be well cooled else it will stick to the fingers.)

3. Repeat above after carefully washing the hands. What conclusions may be drawn regarding the sanitary value of washing?

4. Is dry sweeping a sanitary procedure? Expose a dish during the time the janitor is sweeping the laboratory. If possible, expose one just preceding sweeping for comparison. Both should be exposed for the same length of time. What are your conclusions?

5. Does a vacuum cleaner have sanitary value? Expose a dish as in Problem 4 in a room in which a vacuum cleaner is being operated.

6. Is dusting a sanitary procedure? Expose one plate in a room that is being dusted with a feather duster or a dry cloth. Expose another similarly in a room in which a damp cloth is being used to remove the dust.

7. What is the effect of temperature upon bacterial growth? Prepare six dishes in such manner that they will be approximately equally inoculated with bacteria. This may be done as follows: Pour a few drops of liquid from the decaying beans used in the preceding exercise, or from some similar source, into a beaker of warm water. Stir the water until it may be supposed that the bacteria are evenly distributed through it. Melt the agar in six tubes, as directed on page 95. When the tubes and water by which they are surrounded have come to a temperature of about 45° C., add to each tube a small measured quantity of the water from the beaker. One or two drops from a medicine dropper to each tube will be sufficient. Be sure to add the same number of drops to each tube. Pour into petri dishes. Place two dishes in an ice box, two others in a warm place, and let the other two remain on the laboratory desk. Examine them daily and note the differences in size of colonies. What is your conclusion?

8. Do chemical poisons prevent the growth of bacteria? Prepare tubes as above, but in each place small quantities of formalin, boracic acid, or other preservatives. If several tubes are prepared containing varying quantities of the same preservative, it will be possible to secure an indication of the quantity of each which is necessary.

9. Are there bacteria in drinking-water? Proceed as in Problem 7, but inoculate tubes with drinking-water, 5 to 10 drops, instead of with water from the beaker.

10. Are common drinking-cups contaminated? Place the edge of a public drinking-cup in contact with the agar in a dish. Observe results.

References

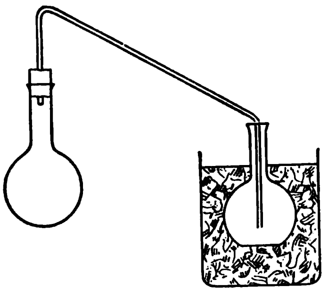
BERGEN and CALDWELL. Practical Botany, chap. xi.
BERGEN and CALDWELL. Introduction to Botany, chap. xiv.

EXERCISE 77

PHYSIOLOGY OF YEAST

Materials. Compressed yeast, which must be fresh; molasses; bottles; flasks; thermometer.

Directions for work. Mix one fourth of a cake of compressed yeast with water, making a thin paste. Add it to a 10 per cent solution of molasses in water. Add a proportionate amount of yeast to pure water. Set both aside in a warm place for examination the next day. It would be well to divide the molasses solution and yeast into three parts. One of these should be reserved for use in the next exercise and the other two used as directed below. Cover all three of them loosely in order to prevent evaporation.



When the yeast culture has stood for twenty-four hours or more, note the bubbles of gas rising through the liquid. Determine as closely as possible their place of origin. In what way, if any, do they appear to be related to the yeast? Collect some of the gas as illustrated. Test with a flame and with limewater. What gas is this? (See Caldwell and Eikenberry, "Elements of General Science," Rev. Ed., pp. 71, 72.)

Put a quantity of the solution into a flask arranged as illustrated. Heat until a small amount of distillate has collected or until the thermometer goes above 80° C., cooling and condensing the vapors in the receiving flask. Identify the distillate. Note its odor and how rapidly it evaporates, and try to ignite some of it soaked in filter paper. What is the source of the two substances which have been discovered in the solution? Consider that the three essential materials in the solution are water, sugar, and yeast. Which of these is increasing? Which is decreasing? Which is remaining apparently unchanged?

EXERCISE 77 (*Continued*)

Sum up in the conclusion of your notes what you know regarding the life-processes of yeast.

References

BERGEN and CALDWELL. Practical Botany, pp. 232, 233.
BERGEN and CALDWELL. Introduction to Botany, pp. 246, 247.

EXERCISE 78

STRUCTURE OF YEAST

Materials. Fresh cake of compressed yeast and one of the cultures from preceding exercise; microscopes; slides and covers.

Directions for work. Rub the fresh surface of the yeast cake lightly across the slide. Add a drop of water and cover glass. Examine with a microscope. The small objects seen are yeast plants and starch grains. If you cannot distinguish one from the other, add a bit of iodine solution, which will enable you to distinguish the starch. (How?) When you are sure you can recognize the yeast plants, prepare another slide without iodine. In your notes tell what you have learned about the shape, relative size, color, and structure of the yeast plants.

Prepare another slide from the scum on one of the cultures of yeast in molasses solution. This yeast you know to be in active condition (Exercise 77). Find out, by examining it, the method by which the number of yeast plants increases. Describe the growth and reproduction of yeast.

References

BERGEN and CALDWELL. Practical Botany, pp. 232, 233.
BERGEN and CALDWELL. Introduction to Botany, pp. 246, 247.

EXERCISE 79

PREPARATION OF MOLD CULTURES

Materials. Molds will grow on almost any organic material if it is kept damp. Their spores reach substances in much the same manner as do bacteria. In order to have on hand a variety of molds for study, it is advisable to prepare a number of cultures. These should be observed from day to day and the facts regarding the growth of the molds recorded.

Directions for work. 1. Moisten a piece of bread which has been exposed to the dust of the air. Cover with glass to prevent evaporation while allowing observation.

2. Put a piece of banana peel under a cover as in 1.

3. Inclose a lemon or part of one in a similar manner.

4. In a dish place various vegetable scraps and cover.

5. Cover a dish of fruit and gelatin dessert, or similar preparation.

All of the preparations suggested above should be covered with glass to allow observation without disturbing the mold or exposing it to the air. It is usually convenient to place the material in a small shallow dish and cover with an inverted drinking-glass. The experiments should be placed in a warm location.

EXERCISE 80

BREAD MOLD

Materials. The rather coarse cottonlike growth that commonly appears on bread is referred to as bread mold or black mold. It is often not the first mold to appear on bread, but its growth is so vigorous that it soon covers up the others. It may be recognized by its large white heads (sporangia), which soon turn black. (See textbooks, under the heading *Rhizopus nigricans*, for descriptions.) It may be found also in some of the other cultures. If it appears on the gelatin, the transparency of the medium will allow the whole plant to be seen.

Directions for work. Study the plant and its manner of growth with the naked eye and the hand lens. Describe it carefully. Look for it in all the other cultures, including the cultures of bacteria. If it can be found growing on the gelatin or the agar cultures made in Exercise 76, study the distribution of the plant below the surface.

If the plant has spread from the bread to the surface of the containing dish, as commonly occurs, note how it advances into new territory.

References

BERGEN and CALDWELL. Practical Botany, pp. 214–217.
BERGEN and CALDWELL. Introduction to Botany, pp. 235–239.

EXERCISE 81

DETECTION OF MOLDS IN AIR AND IN OTHER PLACES

Materials. Sterilized petri dishes; one of the common dessert gelatins which are sold under various trade names, or agar culture medium.

Directions for work. Tests for the presence of mold spores in the air and in various media may be made in a manner similar to that described for bacteria (Exercise 76). In fact, it is probable that many mold colonies were found among the bacterial colonies. Very satisfactory substitutes for agar are the various sorts of gelatin sold for household use. If these are purchased in sealed packages, they will be practically sterile and will need no further sterilization than the boiling needed to dissolve them. Pour in shallow dishes and allow to cool in the usual way, or some of the material may be placed in sterile test tubes and plugged with cotton.

Expose the petri dishes with the culture medium in situations similar to those suggested for the bacterial cultures (Exercise 76), or inoculate them directly from other cultures of mold.

Keep several petri dishes or test tubes uninoculated, as a check upon the sterile character of the medium. Set all the dishes in a warm place, where they may be examined from time to time without disturbing them. From day to day note carefully the first appearance of the colonies and the changes that take place. The cultures will afford the materials for use in the following exercises.

EXERCISE 82

BLUE MOLD, OR BLUE MILDEW

Materials. The cultures prepared in the preceding exercises; hand lens; if possible, microscope, slides, and covers.

Directions for work. Study the colonies and determine the manner of increase in size and the differences between the older and younger parts of the colonies. If you have colonies in a transparent medium, such as the gelatin, note the growth of the colony in the medium. If it is possible to view a colony on gelatin through a low-power objective (one-inch or two-inch) of the microscope, it will be possible to secure a very good idea of the whole plant in its natural relations.

What evidence, direct or indirect, do you have that the mold is drawing food from the substance upon which it grows? Will it grow in the dark? Does it have any observable effect on the substance upon which it grows?

Blue vitriol (copper sulphate, $CuSO_4$) is commonly used in the making of fungicides. Place a small piece of a crystal, not much larger than a pinhead, near a growing colony of blue mold and note the result after several days. Does it have a fungicidal (fungus-destroying) action? Do the same with a drop of lime-sulphur mixture if you can secure it.

If compound microscopes are available, very carefully pick up a few fibers of the mold and mount in a drop of alcohol on a slide. Add water to replace evaporation of the alcohol. Examine the character of the hyphæ, the branching, and the manner of forming spores. Record the principal facts in a drawing. Compare with illustrations in books to discover the name.

References

BERGEN and CALDWELL. Practical Botany, pp. 231, 232.
BERGEN and CALDWELL. Introduction to Botany, p. 245.

EXERCISE 83

YELLOW MOLD, OR YELLOW MILDEW

Materials. Same as in preceding exercise.

Directions for work. This mold may be recognized by its yellowish or olive color. It often grows scattered rather than in compact colonies.

Study may be made similar to that of blue mold. The method of formation of spores will enable identification by comparison with figures in books.

EXERCISE 84

LILAC MILDEW—A PARASITIC FUNGUS

Materials. Leaves of lilac infected by the fungus. The fungus is common on lilac leaves in the summer, giving them a whitish, moldy appearance. Leaves should be collected in June, when the powdery appearance is first noted, and again in autumn, when minute black dots may be seen.

Directions for work. 1. Early summer leaves. Note the location of the mycelium, where it appears most vigorous, and its relation to the lilac leaf. Use microscope with low power if available, and compare your observations with your study of the relation of molds to the agar or gelatin.

With the hand lens note the spores, and, if possible, use microscope to discover method of formation of spores, as in your study of blue mold etc.

2. Examine the leaves collected in the autumn and determine whether the black bodies are related to the fungus. Mount for microscopic examination and crush by pressure on the cover glass. What evidence do you see of spores?

References

BERGEN and CALDWELL. Practical Botany, pp. 229, 230.

BERGEN and CALDWELL. Introduction to Botany, pp. 244, 245.

EXERCISE 85

WHEAT RUST—A DESTRUCTIVE PARASITE

Materials. Stems and leaves of rusty wheat or oats, collected just before harvest; wheat plants or stubble showing black rust, collected in late summer or autumn; leaves of barberry showing rust.

Directions for work. 1. *Red rust.* Study the distribution, shape, and general appearance of the red spots on both stem and leaves of the wheat plant. Write a description intended to assist in identifying the disease. Scrape out some of the contents of one of the red spots and examine under high power of microscope. Add to your description the facts you discover.

If possible, examine rusty grain in the field to determine the character of the injury by rust. Note especially the effect upon the general vigor of the plant, the strength of the straw, and the quality of the grain. If you cannot visit fields at this time, question farmers and others on the above points.

Find out, by reading and by talking to practical farmers, about the effect of weather conditions upon rust and about the susceptibility of different varieties of wheat, oats, and other grains to rust. Does the information from all sources appear to be equally reliable? Sum up what you find to be the facts on this topic.

2. *Black rust.* Study in manner similar to that outlined for the red phase. The black rust is the same plant as red rust, but a different kind of spore is produced later in the summer. As this phase appears after harvest, little damage can be done directly. Note dates of collection of red and of black rust.

If you can examine these spores microscopically, note their characteristics in comparison with the red-rust spores. Are they in any way particularly fitted for the season of the year which follows the time of their production?

3. *Rust on barberry.* The "cluster cups" of wheat rust may be found on the under side of barberry leaves. Study and describe sufficiently for identification. Smaller growths of the fungus may be detected upon the upper side of the leaves.

These cluster cups are produced by the same fungus that produces red and black rust in wheat, but the fungus grows somewhat differently in barberry. Find out, by reading, the relation of barberry to rust in wheat fields and the whole story of the life history of the wheat rust.

Good microscopic sections will assist in the study of all three of the above forms.

References

BERGEN and CALDWELL. Practical Botany, pp. 243–245.
BERGEN and CALDWELL. Introduction to Botany, pp. 253–256.

EXERCISE 86

FUNGI WHICH CAUSE PLANT DISEASE

Materials. Fungi collected on field trips; books of reference.

Directions for work. Study and describe as many kinds of fungi as may be found in field trips. Many of these may be identified with considerable certainty by inquiry and by reference to books.

Study and describe each with reference to the following points:

1. General appearance on plant.
2. Type and extent of damage produced.
3. Means by which host may be infected.
4. Prevention of infection and destruction of parasite.

References

BERGEN and CALDWELL Practical Botany, pp. 221, 223, 226–234, 240–247.

BERGEN and CALDWELL. Introduction to Botany, pp. 239–245, 252–256.

Books for Identification

DUGGAR. Fungous Diseases of Plants. Ginn and Company.

STEVENS. The Fungi which cause Plant Disease. The Macmillan Company.

EXERCISE 87

A MUSHROOM

Materials. Any common mushroom (or toadstool) will answer. If no other material is available, the common field mushroom (*Agaricus*) may commonly be purchased in the market, either fresh or canned, but, if possible, the study should be made on fresh material collected by the class.

Directions for work. Find mushrooms in the field. Determine whether they are parasites or saprophytes by field study. Note the places where they are found and the kinds of material to which they are commonly related and from which they may secure food. Find and trace so far as possible the fine, thread-like underground parts. It will be necessary to wash away the soil carefully about the base of the mushroom in order to discover the underground parts, or a piece of the soil may be brought into the laboratory for examination. These underground hyphæ constitute the nutritive body of the mushroom. The toadstool is the fruiting body, producing the spores.

Study the fructification, noting (1) the stalk, (2) the cap, (3) the gills. Some kinds will show also (4) a cup at the base of the stalk and (5) a ring around the stalk below the cap.

Describe the mushroom. If possible to secure several kinds, describe each kind with sufficient clearness to enable one to distinguish them from your descriptions.

Identify any that you find in the field by the use of proper books.

References

BERGEN and CALDWELL. Practical Botany, pp. 247–253.

BERGEN and CALDWELL. Introduction to Botany, pp. 256–260.

Book for Identification

PATTERSON and CHARLES. "Mushrooms and Other Common Fungi," *Bulletin No. 175*, U. S. Dept. Agr., 1915.

EXERCISE 88

WOOD-ROTTING FUNGI

Materials. Examine standing trees and fallen logs for any large fungi found growing upon living or dead wood. Bracket or shelf fungi and the oyster-shell fungus are common. Collect these, together with pieces of the wood and bark to which they are attached.

Directions for work. In the laboratory examine the collected materials. Note that the fruiting bodies often have no stalk, or a very short one, and that this stalk is in many forms attached at the edge of the cap rather than in the center. The most marked feature of the group to which most of the wood-rotting fungi belong (*Polyporaceæ*) is that the spores are borne not on gills, as in the mushrooms (*Agaricaceæ*), but in numerous small pores found on the under side. Any gill fungi found in the collection probably belong to the mushrooms.

Examine the wood and bark for the fine, whitish fibers of the mycelium and trace it through the wood as far as possible. Compare the fungus-infected wood with sound wood as to weight, hardness, strength, and color.

Do you find results of fungus attack in living trunks or branches or only in dead ones? Is it possible that these fungi cause the death of wood? If so, what would be their importance with relation to the lumbering industry?

In the case of any which attack only dead wood, what is their importance in the forest? What is their possible importance with relation to telephone poles, fence posts, and railway ties, and in lumber yards? What direct evidence have you of their actual importance in the latter cases?

Reference

HUMPHREY, C. J. "Timber-Storage Conditions," *Bulletin No. 510*, U. S. Dept. Agr.

EXERCISE 89

CLASSIFICATION OF FUNGI

Materials. Records of laboratory work on preceding exercises.

Directions for work. Write a brief summary of the distinguishing characters of each of the following subclasses of fungi, and add under each subclass a list of names, so far as you know them, of the fungi studied which belong to that group.

CLASS : *FUNGI*

1. Subclass *Phycomycetes.*
2. Subclass *Ascomycetes.*
3. Subclass *Basidiomycetes.*

References

BERGEN and CALDWELL. Practical Botany, chaps. xiv, xv.
BERGEN and CALDWELL. Introduction to Botany, chap. xvi.

EXERCISE 90

PLEUROCOCCUS — THE GREEN-SLIME ALGA

Materials. Collect pieces of green-stained bark from the north sides of trees or chips of wood from fences. Moisten some of them, place in a dish with a glass cover, and expose to diffuse light. Under these conditions the alga will grow indefinitely. In most parts of the country the material may be collected any month of the year.

Directions for work. Examine a specimen of the dry bark with naked eye and hand lens, noting the powdery appearance of the masses of *Pleurococcus*. Examine some of the moistened material with the microscope, preferably after it has had several days to grow. Describe the plant.

Determine by microscopic examination how new plants are produced.

How do you suppose *Pleurococcus* secures food? Do you suppose it to be an independent plant, or is it saprophytic on the bark? Experiment in the following way: Secure a piece of porous earthenware from a broken flowerpot. Heat it to sterilize, and place it in a dish containing about a quarter inch of water. Place a small quantity of *Pleurococcus* on the earthenware and put the whole in a favorable place for growth. Examine from time to time for a week or two to determine whether the plants can grow without bark or other similar food material.

References

BERGEN and CALDWELL. Practical Botany, pp. 188–191.
BERGEN and CALDWELL. Introduction to Botany, pp. 221–223.

EXERCISE 91

A FUNGUS PARASITIC ON AN ALGA

Materials. Lichens may be readily found on the bark of trees, on fences, on stones, or on the soil. (See textbook illustrations for assistance in identification.) Common forms are greenish gray, but some are almost black and a few are yellow or orange.

Directions for work. Place a fragment of a lichen on a glass slide and tease it to pieces with a needle. Mount in water and examine with a hand lens, or, better, with a microscope. You should be able to make out small green cells and colorless filaments. The green cells are algæ, which may be one-celled, like *Pleurococcus*, or the cells may be joined into chains or filaments.

How could the alga secure food and water? How would the fungus secure these necessities? Compare the condition of lichens after a rain with the condition of the same plants during a dry period. What seems to be the relation between the fungus and the alga?

Study and describe as many kinds of lichens as you are able to find. The cups found on some of them are the fruiting bodies.

References

BERGEN and CALDWELL. Practical Botany, pp. 235–239.

BERGEN and CALDWELL. Introduction to Botany, pp. 247–251.

EXERCISE 92

SPIROGYRA — THE POND SCUM

Materials. Abundant in most parts of the country as a frothy green scum on the surface of shallow pools. Fruiting material, when found, should be preserved in formalin.

Directions for work. With the forceps remove and mount a few of the plants. As you are securing the material note the length of the filament and its appearance to the naked eye.

In studying the filament under the microscope note the arrangement of the cells and whether they seem to be definitely attached to each other. Also, is there any differentiation between different parts of the filament, or are all parts alike?

Study several cells in detail: observe (1) cell, (2) peculiar spiral chloroplast (one or more), (3) cytoplasm (lining the cell wall, very transparent, best seen after staining with iodine), (4) nucleus (imbedded in an irregular mass of cytoplasm near center of cell). This mass of cytoplasm is suspended by delicate threads running from it to the cytoplasm next the cell wall. The space not occupied by the cytoplasm is filled with cell sap (mainly water) and is called the cell vacuole.

Do you find any cells which, from their length or for any other reason, appear to have been lately formed by division? If so, draw them *in outline.*

Draw one or two cells *in detail.*

How would this plant secure the essential materials for its nutrition? Is there any evidence, such as giving off oxygen or presence of starch in the cells associated with the chloroplasts, that it carries on photosynthesis? Devise your own methods for determining these facts.

References

BERGEN and CALDWELL. Practical Botany, pp. 191–193.

BERGEN and CALDWELL. Introduction to Botany, pp. 223–225.

EXERCISE 93

REPRODUCTION IN *SPIROGYRA*

Materials. *Spirogyra* reproduces freely in the spring or early summer. Material should be collected at that time, examined, and, if showing reproductive stages, should be preserved for use in the laboratory when fresh material is not available.

Directions for work. It is not usual to be able to find *Spirogyra* in reproductive condition just when wanted. For that reason you will be supplied with preserved material in bottles. Do not remove more material than needed.

When you have mounted a slide in the usual way, examine it under the low power for reproductive stages (see textbook). If you are quite confident that there is nothing of interest on the slide, wipe the material off and prepare another promptly.

Find and draw the following stages in the formation of the spore:

1. Protuberances from cells of two adjacent plants not yet united.
2. Protuberances united.
3. Gamete passing through the tube.
4. Completed spore.

Draw stages in whatever order you find them, but label properly and try to arrange in order.

This method of spore formation by the union of two cells is called sexual spore formation, or sexual reproduction.

In this case is there any visible difference between the two filaments, or the conjugating cells, corresponding to the male and female sexes in higher plants or animals? When the spores have been formed do you note any difference between the filaments? Since each spore is a single cell, formed by the union of two cells, how has the total number of cells changed? Would the spores possess any advantage over the filaments if the pond should dry up?

References

BERGÉN and CALDWELL. Practical Botany, pp. 193, 194.

BERGEN and CALDWELL. Introduction to Botany, pp. 224, 225.

EXERCISE 94

EDOGONIUM

Materials. This alga may be found attached to sticks and stones in ponds and streams. Fruiting material should be preserved when found.

Directions for work. Compare the cells with those of *Spirogyra.* Examine the attached end of the filament for the peculiar holdfast. This is particularly well seen on young filaments.

If the material is fruiting, some of the filaments will contain thick-walled sexual spores similar to those seen in *Spirogyra.* Do all cells of the filament form sexual spores? Other filaments may show these in earlier stages, before the thick wall has formed, illustrating all the stages in the transformation of an ordinary vegetative cell into a sex cell (egg).

Certain cells of the same filament or of other filaments may be found which have divided transversely, forming several smaller cells. In each of these are formed two small sex cells (sperms). These escape into the water and may swim to the large sex cells and unite with them, one small cell uniting with one large one. Afterward the thick wall forms.

Can you distinguish the sexes here? Is there any considerable amount of food material stored in either sperm or egg or in the spore? What is the advantage?

Reference

BERGEN and CALDWELL. Practical Botany, p. 202.

EXERCISE 95

STUDY OF GREEN ALGÆ

Materials. Collections brought in from field trips along streams, ponds, and lakes.

Directions for work. Familiarize yourself with the great variety of forms among the algæ by examining with the microscope all the materials collected, including the sediments. A large number of kinds of algæ will be found. Some of these may be recognized by reference to the textbook. Those who are more interested may be able to identify others by the use of the proper books.

References

BERGEN and CALDWELL. Practical Botany, pp. 188–206, 212.

BERGEN and CALDWELL. Introduction to Botany, chap. XV.

Book for Identification

COLLINS. Green Algæ of the United States. Tufts College Studies.

EXERCISE 96

VEGETATIVE STRUCTURE OF A MOSS PLANT

Materials. Growing moss plants collected by the class on field trips; preserved materials to supplement the collections if necessary.

Directions for work. Study the plants with the object of finding out how well fitted they are to perform their nutritive work in competition with other plants and in the struggle against unfavorable natural conditions. Compare constantly with what you know of simpler plants (algæ) and more complex plants (flowering plants).

1. How does the moss plant secure food? Does it have chlorophyll? stem? leaves? In what way, if any, is it better equipped than the common algæ to expose a large surface to the light without being readily shaded? In a competition for light between an alga like *Spirogyra* and a moss growing in the water, as peat moss, which would probably survive? Which, in the case of a land alga, like *Pleurococcus* or *Vaucheria*, and a common moss?

Would a moss or a flowering plant have the better opportunity to secure light and carry on photosynthesis? Can you find in the moss plant strengthening tissue such as you found in flowering plants, which would support large leaves and tall stems? What is your opinion of the place of the mosses in the competition for light among plants?

2. Consider the problems of securing and retaining water in relation to the moss plant, keeping in mind particularly the mosses that live upon land.

What equipment does the moss plant have for securing water from the soil? Might it be able to secure water from even a very small distance beneath the surface? How does its equipment for absorption from the soil compare with that of the algæ? with that of the flowering plants?

How well is the moss adapted to retain water? Does it have an epidermis, layers of hairs, cuticle, or other protective devices such as you found on leaves and other parts of flowering plants? Would you expect to find a high or a low rate of transpiration

from mosses in dry air? Does the moss have a well-developed transportation system for water, similar to the fibrovascular bundles of higher plants, which would be capable of transporting water for a large leaf area? Upon the basis of these facts, can you account for the restriction of the mosses, commonly, to locations with moist soil and moist air. Do you consider them to be more, or less, well fitted to grow upon land than the algæ? than the flowering plants?

References

Bergen and Caldwell. Practical Botany, pp. 257–260.
Bergen and Caldwell. Introduction to Botany, pp. 262–264.

EXERCISE 97

REPRODUCTION OF MOSSES

Materials. Collections of moss bearing the long-stalked spore cases, and material with archegonia and antheridia; prepared sections of archegonia, antheridia, and sporophytes.

Directions for work. Most of the facts of the reproduction of mosses can be worked out only by the aid of the compound microscope. With the exception of 1 this exercise had better be omitted unless the class is an advanced one.

1. Some of the moss plants will bear at the top a leafless stem from one to three inches tall, with an enlargement at the top. When disturbed, clouds of spores may be given off from the enlargement, or sporangium. These are sexual spores.

2. *Antheridia and archegonia.* These may be dissected out from the tips of the leafy stems with needles and examined by the aid of the microscope. A more careful study can be made from stained sections. (See textbook for details.)

3. The sporangium and stalk (sporophyte) grows from a fertilized egg. (See textbook.) Development of the sporophyte may be followed in sections.

References

BERGEN and CALDWELL. Practical Botany, pp. 260–265.
BERGEN and CALDWELL. Introduction to Botany, pp. 264–266.

EXERCISE 98

VEGETATIVE ORGANS OF THE FERN

Materials. Entire fern plants, either wild or potted (young plants about six inches high will answer admirably); sections of underground stem of fern; sections of fern leaves.

Directions for work. Study the fern, as you did the moss, with reference to its equipment for its vegetative work.

1. How does the fern's equipment for photosynthesis compare with that of moss and alga? with that of flowering plants? Consider ability to rise above competitors, supporting tissue, amount of surface exposed, palisade tissue, intercellular spaces in leaf, and stomata allowing entrance of carbon dioxide.

2. How does the fern's equipment for securing, transporting, and retaining water compare with that of the other kinds of plants? Consider roots and root hairs, fibrovascular bundles, epidermis, hairs, cuticle, and veins.

3. From what you have seen and read regarding the places where ferns grow, their numbers, size, and distribution, what is your opinion of their ability to compete with other plants in the struggle for existence?

References

BERGEN and CALDWELL. Practical Botany, pp. 274–280.
BERGEN and CALDWELL. Introduction to Botany, pp. 269–273.

EXERCISE 99

REPRODUCTION AND DISPERSAL OF THE FERN

Materials. Fern leaves with fruit dots on under side may be secured either in the woods or in greenhouses.

Directions for work. Study the arrangements of the fruit dots on the different leaves available. This is one of the characters that assist in distinguishing different species. Record in notes or sketches the different plans of distribution found. Record also the shape and attachment of the scale which covers the fruit dots.

Scrape off onto a glass slide the contents of one of the dots, selecting one that has not yet turned brown. Examine with a hand lens and microscope. The sporangia will be seen, and possibly the spores may be seen within them. If a compound microscope is used, crush some of the sporangia by pressure on the cover glass and observe the spores. These are asexual spores.

Study dispersal by the following method: Place a fern leaf with almost ripe sporangia on a piece of white paper, fruiting surface downward. Allow it to remain undisturbed for a day or two. The drying of the sporangia will cause them to open and shed their spores. Examine the paper for spores and for evidence that they are forcibly discharged by the sporangia. What would be the result as to dispersal of the spores if they were similarly discharged from a leaf in position on the plant? What if the wind were blowing?

Some of the spores may be scraped from the paper and placed on a slide for examination with the microscope.

Common ferns may be readily identified by reference to proper books.

References

Bergen and Caldwell. Practical Botany, pp. 280–282.

Bergen and Caldwell. Introduction to Botany, pp. 273, 274.

Book for Identification

Gray. New Manual of Botany, 7th edition. American Book Company.

EXERCISE 100

THE FERN GAMETOPHYTE

Materials. Fern gametophytes may be found in greenhouses where ferns have been shedding spores. They are small, delicate, heart-shaped green bodies not more than an eighth or a quarter of an inch in diameter. (See textbooks for illustrations.) Fern gametophytes are rarely found in the field even by experienced collectors. The exercise may well be given as a demonstration with any but the most advanced classes.

Directions for work. The fern spores do not grow into plants like the original. A spore when germinated produces a small heart-shaped plant called the fern gametophyte (or the prothallus). Examine a gametophyte, noting its characteristics.

Consider its ability to secure food and water and its general ability to succeed in the struggle for existence, using the same outline as was used in the study of the moss plant. How does the gametophyte generation of the fern compare with the generation of the fern just studied (sporophyte) in equipment for successful competition with other plants?

The gametophyte produces sexual cells (gametes) which unite to form sexual spores. From these the familiar spore-bearing plant (Exercise 99) is produced. Young sporophytes may be found attached to some of the gametophytes.

In the life history of the fern, therefore, sporophyte and gametophyte alternate. Is the gametophyte a weak or a strong link in the life history?

The leafy moss plant, with which you have been comparing the fern, is a gametophyte; the spore case and stalk are the sporophyte generation. The moss sporophyte is parasitic. Comparing the fern with the moss, has the sporophyte become more, or less, important? Has the gametophyte become more, or less, important?

References

BERGEN and CALDWELL. Practical Botany, pp. 282–286.

BERGEN and CALDWELL. Introduction to Botany, p. 274.

EXERCISE 101

VEGETATIVE STRUCTURE OF THE PINE

Materials. Branches with leaves and cones; sections of wood and leaves, either free-hand or microtome cut.

Directions for work. Determine whether the pine tree is structurally well equipped with the tissues needful to perform its nutritive work in competition with the flowering plants. Proceed as in the study of mosses and ferns.

Examine standing trees with regard to the extent of root system, the height and strength of stems, and the amount of leaf surface.

Examine the leaves and stems in more detail, comparing with your descriptions and drawings of leaves and stems of flowering plants and ferns.

1. *Leaves.* Note arrangement in clusters and number in each cluster. Note size and shape of leaves. Ascertain the facts regarding epidermis and cuticle, palisade tissue, stomata and internal air passages, and veins. Do the leaves seem suited to a dry climate or a moist one? Is the cold northern winter a dry or a moist season so far as the leaves are concerned?

2. *Stem.* Compare the gross and microscopic structure of the wood with that of dicotyledonous stems (Exercise 7), using your notes and drawings. What are the points of resemblance between gymnosperm and dicotyledonous stems? What are the points of difference?

3. How well equipped does the pine tree appear to be in comparison with the flowering plants studied earlier in the course?

Look up the facts of the actual success of the pines and see whether the facts agree with your conclusion given above. Refer to textbooks, encyclopedias, geographies, etc. Note such facts as the geographic distribution of the pines, the area of the pine forests, the abundance of individuals in the forest, and the size and age of individual trees.

References

BERGEN and CALDWELL. Practical Botany, pp. 299–306.
BERGEN and CALDWELL. Introduction to Botany, pp. 268–289.

EXERCISE 102

REPRODUCTION OF THE PINE

Materials. Cones of the season containing seeds, one-year-old cones on branches, and branches with young staminate and pistillate cones; piñon seeds.

Directions for work. The familiar pine tree is the sporophyte generation, bearing two kinds of asexual spores, one of which is illustrated by the pollen grains. The gametophyte generation is so reduced that it can be studied only by the aid of the compound microscope. The gametophytes will not be included in the laboratory work.

1. *Staminate cones.* The cones are composed of a central axis bearing overlapping leaves. Split a cone through the center to see the attachment of the scales to the axis. Pick off one of these scales, or stamens, and find the two pollen sacs (sporangia) on the under surface. Make a diagram to show the arrangement of the scales on the stem and another to show the form of the stamen and its pollen sacs.

Break open one of the pollen sacs and mount the pollen for observation with the microscope. Note the two wings which assist in distribution by the air.

The pine is wind-pollinated. Is this an economical method so far as amount of pollen required is concerned? Place a cluster of fresh cones which have not shed their pollen in a cup and allow them to remain for several days. Note the quantity of pollen collected.

2. *Young pistillate cones.* Note the arrangement of the scales. Remove several and find the two ovules on the base of each. Make a diagram showing the arrangement of the scales on the axis and the position of the ovules on the scales.

Are these ovules inclosed in an ovary as are those of flowering plants? Can the pollen grains which the wind deposits on these cones come into actual contact with the ovules, or is there a style, stigma, etc., as in flowering plants?

3. *One-year-old cones.* Examine scales from these to see the growth in scale and ovules, now become seeds.

4. *Two-year-old cones.* Examine the scales and seeds. Draw a scale with seeds in position, showing wings of the seeds. Experiment with the seeds, as you did with the fruits of maple etc., to determine their adaptation for dispersal by wind. If mature cones which have not shed their seeds can be secured, allow several of them to lie on the table for several days and note how the seeds are released from the cones.

5. *The embryo.* Carefully pick off the hard outer coating of a seed and remove the white interior. Bit by bit, pick off the outer part of the white interior until you come to the embryo within. If you fail on the first one, try another. The large seeds of the piñon, often sold under the name of fine nuts, are particularly satisfactory for this study. Make a drawing of the embryo, showing stem and leaves. Make a diagram showing relative position of embryo, food supply, and seed coat.

Does the seed of the pine appear to be equivalent to the seeds of flowering plants which you have studied, on such points as means of dispersal, protective covering, food supply, and condition of embryo? Do you find any weak point in the life history of the pine similar to the gametophyte generation of the fern?

References

Bergen and Caldwell. Practical Botany, pp. 306–311.
Bergen and Caldwell. Introduction to Botany, pp. 289–292.

EXERCISE 103

THE GYMNOSPERM GROUP

Materials. Collect branches, with fruit if possible, of any needle-leaved evergreen trees in your vicinity.

Directions for work. Describe each of the kinds found, being careful to state clearly the characteristics which distinguish each.

Describe the group as a whole, emphasizing the characteristics which are common to all the gymnosperms you know.

The gymnosperms which are native to the United States may be readily identified by the use of the books listed under Books for Identification below.

References

BERGEN and CALDWELL. Practical Botany, chap. xviii.

BERGEN and CALDWELL. Introduction to Botany, pp. 282–296.

Books for Identification

BRITTON and BROWN. Illustrated Flora of the Northern States and Canada. Charles Scribner's Sons.

CHAPMAN. Flora of the Southern United States. American Book Company.

COULTER and NELSON. Manual of Rocky Mountain Botany. American Book Company.

GRAY. New Manual of Botany, 7th edition. American Book Company.

HOUGH. Handbook of the Trees of the Northern States and Canada. Published by the author.

PIPER and BEATTY. Flora of the Northwest Coast. State College of Washington.

RYDBERG. Flora of Colorado. *Bulletin No. 100*, Colo. Agr. Exp. Sta.

SUDWORTH. "Trees of the Pacific Slope." Forest Service, U. S. Dept. Agr.

EXERCISE 104

THE STAMEN OF A FLOWERING PLANT (ANGIOSPERM)

Materials. Stamens from flower of lily or similar plant, but stamens from almost any flower can be used; slides showing cross sections of anthers with pollen.

Directions for work. The structure of the vegetative parts of the flowering plants (properly called angiosperms) has been studied previously (Exercises 1–74), as is also true of some of the facts about the flowers. Only a few of the details of reproduction will be presented here. The gametophytes of angiosperms are more reduced than those of gymnosperms.

Examine a stamen which has not shed its pollen and note the pollen sacs (sporangia). How many are there? If the anther is cut across with a sharp knife, the relation of parts may be the more readily seen; use a lens.

If you have slides with cross sections of anthers, examine them with the low power of the microscope. Make a diagram showing the shape and relation of parts.

Place some of the pollen grains on a slide without water or a cover glass. Examine with the low power of the microscope. If you will set the microscope in a brightly lighted place and turn the mirror so that no light is reflected from below, the pollen grains will be seen in their natural colors against a dark background.

References

BERGEN and CALDWELL. Practical Botany, pp. 110, 111.
BERGEN and CALDWELL. Introduction to Botany, pp. 129, 299.

EXERCISE 105

POLLINATION

Materials. Flower of lily, or other large flower.

Directions for work. Touch with a camel's-hair brush an anther which is shedding pollen, and then bring the brush into contact with a stigma on which no pollen is visible. Examine the stigma after touching with the brush. Do you find any evidence that pollen can be transferred by this means? How may the lily be pollinated in nature?

Examine stigmas in flowers of different ages, noting whether there is anything in the condition of the stigma at any time that favors the adherence of the pollen. If such a condition is found, does it occur at the time the anthers in the same flower are shedding pollen, before shedding, or after? How would this affect the possibility of self-pollination?

Make a similar examination of flowers of several different kinds with reference to the relation between the time of shedding pollen and the condition of the stigma.

References

BERGEN and CALDWELL. Practical Botany, pp. 325, 326, chap. viii.
BERGEN and CALDWELL. Introduction to Botany, pp. 300, 301, chap. x.

EXERCISE 106

GERMINATION OF POLLEN GRAIN

Materials. Sweet-pea flowers; cane-sugar sirup.

Directions for work. Mount pollen on a slide in cane-sugar sirup and cover with a cover glass. To avoid crushing the pollen grains place small pieces of broken cover glass under the edges of the cover. Set aside in a covered dish containing a sponge saturated with water in order to prevent evaporation. Examine from time to time.

The sugar sirup should be made by dissolving cane sugar in water. Sweet-pea pollen will commonly grow in sirup with a concentration of from 10 to 15 per cent. It is advisable to prepare a series of slides with sirups of differing strengths in order to be sure that some of them will show germination.

References

BERGEN and CALDWELL. Practical Botany, pp. 115–117, 325–326.

BERGEN and CALDWELL. Introduction to Botany, pp. 134–136, 300–302.

EXERCISE 107

OUTLINE FOR THE STUDY OF COMMON FLOWERING PLANTS

Materials. The plants should be collected in the field by the pupils if that is possible. One object of the work should be to secure an acquaintance with the plants of the neighborhood. The amount of this work must be adjusted by the teacher to the time available. Do not use for these studies rare plants or those in danger of extermination.

Directions for work. Study each plant systematically and describe it carefully, noting particularly the distinguishing characteristics.

1. General appearance in the field: herb, vine, shrub, tree.
2. Stem: woody or herbaceous; character of internal structure; height; character of branching; peculiarities of buds, bark, etc., that might assist in identification.
3. Root system, so far as you are able to learn about it.
4. Leaves: arrangement, size, form, venation.
5. Flowers: arrangement, color, form.
6. Calyx and corolla.
7. Stamens.
8. Pistil and fruit.
9. Pollination: manner of pollination and characteristics that might assist in securing cross-pollination; observed visits of insects etc.; means of preventing self-pollination.
10. Seeds and seed dispersal; record of field observations on dispersal.
11. Name: to be secured by the aid of manuals and floras.

References

BERGEN and CALDWELL. Practical Botany, chap. xx, review chaps. iii–ix.

BERGEN and CALDWELL. Introduction to Botany, chap. xviii, review chaps. ii–xiii.

EXERCISE 108

ROOT TUBERCLES

Materials. Roots of clover, alfalfa, or other legumes. The roots should be dug carefully in order that the tubercles may not be broken off in freeing the roots from the soil.

Directions for work. The tubercles are small rounded or oval bodies in connection with the smaller roots. They are easily seen.

After noting their abundance, form, size, and color, break one of them open and examine them microscopically for bacteria.

Examine roots of a number of members of the pea family (*Leguminosæ*) that may be found, to discover how common is the possession of tubercles.

References

BERGEN and CALDWELL. Practical Botany, pp. 374–378.
BERGEN and CALDWELL. Introduction to Botany, pp. 204–206.

EXERCISE 109

VARIATION IN CULTIVATED PLANTS

Materials. An exercise similar to the following may be worked out with almost any cultivated or wild plant. Ears of corn are suggested as being readily available at any season of the year in most parts of the country. Secure ears of corn from the crib without selection in order that the sample may represent the actual character of the crop as nearly as possible. At least a hundred ears should be included in the study by the class if the number of pupils is great enough to make the study without using excessive time. Popcorn or sweet corn may be used as well as field corn.

If it is not desired to use corn, other problems may be taken up based upon other plants. The following are suggested: weight of grains in heads of wheat, oats, etc.; number of heads per plant; number of grains per head; height of cornstalks; height of corn ears from ground; height of timothy plants; number of timothy stems in a clump; length of timothy heads on different plants; number of cotton bolls per plant; weight of cotton per plant; length of cotton fiber.

Directions for work. Weigh each ear of corn. Shell the grains off the cob and weigh grains and ear separately. Tabulate as follows and correct any error that appears:

Weight of entire ear . . . .
Weight of grains only . . . .
Weight of cob only . . . .
Sum of grains and cob . . . .
Error . . . .

Tabulate the weights of grains of all the ears weighed by members of the class in the following blank:

Number of ears with grains weighing

1 g. to 49 g. . . . .
50 g. to 99 g. . . . .
100 g. to 149 g. . . . .
150 g. to 199 g. . . . .
200 g. to 249 g. . . . .
250 g. to 299 g. . . . .

EXERCISE 109 (*Continued*)

From the table of distribution above, answer the following questions: How wide is the variation in this group of ears? Are the variations great enough to be of practical importance? How largely would the yield be affected if all the ears were like the smallest? if all were like the largest? In what groups do most of the ears fall? Which ears would probably be selected for use in an effort to improve the breed of corn?

On cross-section paper make a graph representing the facts shown on the table above.

References

BERGEN and CALDWELL. Practical Botany, pp. 413, 414, 417, 418.

BERGEN and CALDWELL. Introduction to Botany, pp. 173, 174, 181–184.

CALDWELL and EIKENBERRY. Elements of General Science, pp. 290–302. Ginn and Company.

DAVENPORT. Domesticated Animals and Plants, chap. viii. Ginn and Company.

EXERCISE 110

PLANT BREEDING

Materials. Ears of corn from the preceding exercise. The exercise will require a plot of ground, either at the home of a pupil or in the school garden. The results of each experiment will be available to the class of the following year and may be made the basis of the study in Exercise 109. The classes in botany and agriculture may very well coöperate on this experiment.

Directions for work. Select several of the heaviest ears from those studied in the preceding exercise and several of the lightest. Preserve all the data regarding these ears. Assign to each ear a number or other identification mark. Use this to mark the plantings in the field as well as all records.

Plant at least a hundred grains from each ear, planting all the grains from one ear in a row by themselves. If it is intended to continue the experiment in later years, using selections from next year's crop for seed, the rows planted with seed from the poor ears should be located at least several rods from those planted with seed from the best ears. (Why?) Alternate rows should be detasseled. (Why?).

When the crop is gathered at the end of the season, keep the product of each row separate from that of the other rows. Weigh and make table of distribution for each row, or for as many rows as possible, similar to the table in Exercise 109. Graphs may be made also. Compare the record of each row with the record of the ear from which it was planted and with that of the whole group of ears studied in Exercise 109. Has the quality of the crop been changed by selection? Is the progeny of the best ears better than the average of the preceding year? Is it as good in each case as the ear from which it sprung? Are any of the ears better than those from which they sprung?

References

BERGEN and CALDWELL. Practical Botany, chap. xxiii.

BERGEN and CALDWELL. Introduction to Botany, chap. xii.

DAVENPORT. Domesticated Animals and Plants, chaps. ix, xi, xii, xiii, xvi. Ginn and Company.

EXERCISE 111

SOIL FORMATION BY WEATHERING

Materials. Exposed rock surfaces, as cliffs; rock and soil débris at base of cliffs.

Directions for work. Examine exposed rock surfaces carefully to see whether by action of the atmosphere, water, frost, or otherwise, small particles of rock are being loosened. Note also whether larger pieces are being broken off by the expansion of water upon freezing in crevices.

If a rock cliff is being studied, examine the heap of soil and other débris resting against the base of the cliff in order to find out if this débris (the talus slope) is composed of such materials as are being weathered from the face of the cliff.

In your opinion, based upon the facts discovered, has the rock examined contributed to the formation of the soil in its vicinity.

References

BERGEN and CALDWELL. Practical Botany, pp. 436, 437.
Textbooks of physiography.

EXERCISE 112

TO HOW GREAT AN EXTENT DOES PLANT MATERIAL ACCUMULATE IN SOILS?

Materials. Samples of soils, including a clay or sandy soil of sterile character, a black loam, a muck soil, and a peaty soil; sheet-iron soil pans or sheet-iron frying pans.

Directions for work. Dry all the samples of soil in an oven heated to a point just above 100° C. for several days, or if an oven is not available, spread the samples out thinly on pie tins or other shallow dishes and expose to the air. In either case, decide when the drying has been carried to completion by weighing from time to time. When the samples no longer lose weight, they are ready for the experiment.

If the samples have been oven-dried, all of the water will have been driven off; if air-dried, a certain small part of the water will remain in the samples, and the amount will not be the same for the different kinds of soil. It is therefore only by drying in the oven that the soils can be so prepared that exact results will be possible.

Having dried the soils, place a sample of each in a separate iron pan which has been previously weighed. Weigh the pans with soil in them and determine the net weight of soil in each case. Heat each pan with the contained soil by means of a bunsen burner or blast lamp for at least an hour. Note any evidences that organic material, principally plant material, is being burned or driven off.

When the organic material appears to be entirely burned, allow the pans to cool and weigh them again. Determine the amount of loss in each case and calculate the percentage of organic material in each sample. In case you have been using air-dry soils, in which direction would your results be influenced by the fact that the soils were not wholly dry at the beginning of the experiment? That is, would the percentage secured be too high or too low? If you did not heat the samples long enough to complete the burning of the organic material, how would that fact affect the results?

EXERCISE 112 (*Continued*)

So far as you are acquainted with soil types, do you note any correspondence between amount of organic matter and fertility of soil?

Tabulate your results below:

Description of soil No. 1. ....

....

Description of soil No. 2. ....

....

Description of soil No. 3. ....

....

Description of soil No. 4. ....

....

	1	2	3	4
Weight of pan				
Weight of pan and soil before burning				
Weight of pan and soil after burning				
Net weight of soil before burning . .				
Net weight of soil after burning . .				
Loss in weight by burning				
Percentage of organic matter . . .				

Reference

BERGEN and CALDWELL. Practical Botany, pp. 436, 437.

EXERCISE 113

SOIL PARTICLES

Materials. A sandy loam; glass tube one-half inch in diameter and about five feet long; set of sieves. The sieves may be made by tacking wire gauze of different degrees of fineness on small wooden frames.

Directions for work. 1. Soak a small amount of the soil in water for several hours, making a thick mud. Stopper one end of the long glass tube and pour in enough of the soil to fill the tube about six inches. Add water until the tube is filled with water to within an inch of the upper end. Stopper the upper end of the tube and reverse it, thus bringing the tube to a vertical position with the soil at the top. Stand the tube upright and allow it to remain in that position until the following day. As the soil falls through the water the particles will be assorted in accordance with their size and weight.

Describe the composition of the soil with relation to size of particles.

2. Place a good-sized sample of the soil in one of the soil pans and heat over the flame until the organic material is well burned out. Pass it through a series of sieves of increasing fineness, thus separating it into fractions depending on size of particles. The separate fractions of the sample may be weighed and the size of particles estimated by the size of the mesh through which they are able to pass.

Tabulate the facts regarding the physical composition of the soil, which you have secured by the aid of the sieves.

References

BERGEN and CALDWELL. Practical Botany, pp. 434, 435.

CALDWELL and EIKENBERRY. Elements of General Science, Rev. Ed., chap. xxiii.

EXERCISE 114

EFFECT OF LACK OF DRAINAGE

Materials. Prepare two or more waterproof plant pots by soaking common pots in melted paraffin, or use empty fruit or vegetable tins. Each of the pots should have a drainage hole in the bottom, and coarse gravel or broken pieces of flowerpots should be placed in the bottom before filling with soil. This will allow very effective drainage.

Directions for work. Plant wheat, oats, corn, or other grain in both pots. When the seedlings are three or four inches tall, plug the drainage opening in the bottom of one pot with a cork stopper. See that the plug fits tightly. Water both of the pots alike and supply sufficient water from time to time for several days to keep the soil in the plugged pot continually saturated. The excess water will be able to escape from the other pot.

Compare the seedlings in the two pots from time to time for several days, or until there is a very distinct difference between them. What is the effect of lack of drainage? When satisfied on the point mentioned above remove the plug, thus allowing the water to drain from the soil. What is the effect upon the seedlings? Do they recover from the effects of lack of drainage? Do they become the equals of the seedlings which have been grown all the time in properly drained soil?

If a larger number of pots are prepared and subjected to the undrained conditions, it will be possible to unplug one on each of several successive days and thus determine approximately how long the seedlings may remain in saturated soil and yet be able to recover when conditions are corrected.

References

BERGEN and CALDWELL. Practical Botany, pp. 437–441.

BERGEN and CALDWELL. Introduction to Botany, pp. 321–323.

WATERS. Essentials of Agriculture, pp. 122–126. Ginn and Company.

EXERCISE 115

STUDY OF A COMMON WEED

Materials. Any of the common weeds of the vicinity. These should be studied principally in the field.

Directions for work. Examine a weed with the object of determining what characteristics of the plant enable it to be a weed.

1. Ability to maintain itself where present, especially if a perennial plant: such qualifications as deep, tough root system; underground stems; tolerance of shade, drought, excessive water, and dust; ability to grow in poor soil; rapid growth; disagreeable taste, prickles, etc.

2. Ability to reach and take possession of new locations: such qualifications as excellent means of seed dispersal; persistent seeds, not easily injured; rapid-growing seedlings; early germination; spreading rhizomes.

3. Character of injury done: competition with crops by shading; removal of moisture needed for crops, especially in arid regions; parasitism on crop plants; acting as host for insects or fungi injurious to crops, or harboring such insects or fungi; poisonous effects on domestic animals; other injuries to animals or animal products; other important facts characteristic of the weed studied.

4. Means of eradication and prevention.

References

BERGEN and CALDWELL. Practical Botany, chap. xxv.
BERGEN and CALDWELL. Introduction to Botany, chap. xx.

EXERCISE 116

IDENTIFICATION OF COMMON WEEDS

Materials. Common weeds collected from fields in the vicinity. Keep a record of the kind of crop with which each weed was found associated. Collect particularly weeds whose names are not known to you.

Directions for work. If the weeds are in flower, proceed to identify them with the aid of Gray's "Manual" or such other flora as may be applicable to your region. If not in flower, it is possible to identify only by the aid of illustrated floras and "weed books." (See list below.)

Keep notes on each specimen studied. These notes should show the name of the weed, the principal characteristics by which it may be recognized, the crops which it commonly infests, the character of the damage done, and the means of combating.

The value of the notes for future reference will be greatly increased if a specimen of each kind of weed is pressed and mounted on a herbarium sheet with name attached.

Books for Identification

CHESTNUT. "Thirty Poisonous Plants," *Farmers' Bulletin No. 86*, U. S. Dept. Agr.

DEWEY. "Weeds; and how to kill them," *Farmers' Bulletin No. 28*, U. S. Dept. Agr.

"Farm Weeds of Canada," Government Printing Bureau, Ottawa, Canada.

GEORGIA. Manual of Weeds. The Macmillan Company.

MARSH. "Larkspur, or 'Poison Weed,'" *Farmers' Bulletin No. 531*, U. S. Dept. Agr.

MARSH. "Principal Poisonous Plants of the Western Stock Ranges," Bureau of Plant Industry, U. S. Dept. Agr.

NORTON. "Maryland Weeds," *Bulletin No. 155*, Md. Agr. Exp. Sta.

EXERCISE 117

PURITY OF FARM SEEDS

Materials. Samples of any of the smaller seeds, such as the grasses, clover, wheat, and oats. Seeds from local dealers, or from the homes of the pupils, preferred.

Directions for work. Weigh out a sample of the kind of seed to be tested sufficient to contain several hundred seeds. Spread them out on the table and with the aid of a hand lens and a needle sort the kinds of seeds found, putting the perfect seeds of the sort which the sample is supposed to represent in one pile, the broken and imperfect seeds in another, bits of earth, chaff, etc. in another, and each kind of weed seeds or unknown seeds in a pile by itself. Count the seeds of each sort of weed, if not too numerous, and calculate the number of each kind of weed seeds per bushel, based upon the weight of the original sample and the weight of a bushel of the kind of seeds examined. If the usual amount of seed per acre were sown from the lot sampled, how many weed seeds per acre would be sown?

Weigh the weed seeds and the dirt which was sorted out and calculate the percentage of the sample which is not seed of the variety desired.

Means for Identification

BEAL. "Seeds of Michigan Weeds," *Bulletin No. 260,* Mich. Agr. Exp. Sta.

NORTON. "Maryland Weeds," *Bulletin No. 155,* Md. Agr. Exp. Sta.

A named collection of seeds in glass vials.

EXERCISE 118

COMPETITION BETWEEN PLANTS

Materials. A patch of weeds in early spring.

Directions for work. 1. Locate a place where the weeds are coming up thickly. Mark off a space about a foot square. Count the number of weed seedlings. If there are any remains of last year's weeds, estimate the number of weeds that were able to reach maturity on the same area last year. How do the two numbers compare? If possible, follow the area during the season and learn just what becomes of the plants you find there now.

2. Allow the weeds to grow undisturbed along with the crop in a small part of a garden. What is the effect on the crop in comparison with the similar crop in parts of the garden that are cultivated? Can you discover by what means the weeds harm the crop in this particular instance?

References

BERGEN and CALDWELL. Practical Botany, chap. xxv.

BERGEN and CALDWELL. Introduction to Botany, chap. xx.

BERGEN and DAVIS. Principles of Botany, pp. 447–453. Ginn and Company.

CALDWELL and EIKENBERRY. Elements of General Science, Rev. Ed., chap. xxxii. Ginn and Company.